U.S. Fish & Wildlife Service

Middle Mississippi River NWR

Water Resource Inventory and Assessment (WRIA) Summary Report

U.S. Department of the Interior
Fish and Wildlife Service
Region 3 (Midwest Region)
Division of Natural Resources and Conservation Planning;
Bloomington, MN

The mission of the U.S. Fish & Wildlife Service is working with others to conserve, protect, and enhance fish and wildlife and their habitats for the continuing benefit of the American people.

The mission of the National Wildlife Refuge System is to administer a national network of lands and waters for the conservation, management and, where appropriate, restoration of the fish, wildlife and plant resources and their habitats within the United States for the benefit of present and future generations of Americans.

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Author's Note:

There are embedded links throughout this document within the table of contents and indicated by underlined text. A database of the presented data, additional data, documents and the referenced studies will be available as part of a digital document library housed on the Environmental Conservation Online System (ECOS). Geospatial data layers were obtained from the U.S. Fish and Wildlife Service, USGS seamless server, the Environmental Protection Agency, and the Geospatial Data Gateway.

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Chapter 1: Executive Summary

The Water Resource Inventory and Assessment (WRIA) is a reconnaissance-level effort, which provides:

- Descriptions of local soils, topography, and natural setting information
- Historic, current, and projected climate information, including hydroclimate trends
- An inventory of surface water and groundwater resource features
- An inventory of relevant infrastructure and water control structures
- Summaries of historical and current water resource monitoring, including descriptions of datasets for applicable monitoring sites
- Brief water quality assessments for relevant water resources
- A summary of state water laws
- A compilation of main findings and recommendations for the future

The WRIA provides inventories and assessments of water rights, water quantity, water quality, water management, climate, and other water resource issues for each Refuge. The long-term goal of the National Wildlife Refuge System (NWRS) WRIA effort is to provide up-to-date, accurate data on Refuge System water quantity and quality in order to acquire, manage, and protect adequate supplies of water. Achieving a greater understanding of existing information related to Refuge water resources will help identify potential threats to those resources and provide a basis for recommendations to field and Regional Office staff. Through an examination of previous patterns of temperature and precipitation, and an evaluation of forward-looking climate models, the U.S. Fish and Wildlife Service (USFWS) aims to address the effects of global climate change and the potential implications on habitat and wildlife management goals for a specific Refuge.

WRIAs have been recognized as an important part of the NWRS Inventory and Monitoring (I&M) and are identified as a need by the Strategic Plan for Inventories and Monitoring on National Wildlife Refuges: Adapting to Environmental Change (USFWS 2010a, b). I&M is one element of the U.S. Fish and Wildlife Service's climate change strategic plan to address the potential changes and challenges associated with conserving fish, wildlife and their habitats (USFWS 2011). Water Resource Inventory and Assessments have been developed by a national team comprised of U.S. Fish and Wildlife Service water resource professionals, environmental contaminants biologists, and other Service employees.

The WRIA summary narrative supplements existing and scheduled planning documents, by describing current hydrologic related information and providing an assessment of water resource needs and issues of concern. The WRIA will be a useful tool for Refuge management and future assessments, such as a hydro-geomorphic analysis (HGM), and can be utilized as a planning tool for the Comprehensive Conservation Plan (CCP), Habitat Management Plan (HMP) and Inventory & Monitoring Plan (IMP). The CCP (USFWS 2004) is complete for Middle Mississippi River National Wildlife Refuge (MMRNWR).

This Water Resource Inventory and Assessment (WRIA) Summary Report for MMRNWR describes current hydrologic information, provides an assessment of water resource needs and issues of concern, and makes recommendations regarding Refuge water resources. As part of the WRIA effort for this Refuge, water resources staff in the Division of Natural Resources and Conservation Planning (NWRS) received review comments and edits from John Hartleb and Jason Wilson.

This Summary Report synthesizes a compilation of water resource data contained in the national interactive online WRIA database (https://ecos.fws.gov/wria/). The information contained within this report and supporting documents will be entered into the national database for storage, online access, and consistency with future WRIAs. The database will facilitate the evaluation of water resources between regions and nationally. This report and the database are intended to be a reference for ongoing water resource management and strategy development. This is not meant to be an exhaustive nor a historical summary of water management activities at MMRNWR.

1.1 Findings

Over the last 20 years, annual flooding has been much higher than the recurrence intervals computed during the U.S. Army Corps of Engineers flood frequency study in 2003. Stage levels for recurrence intervals 2-20 years are greater with the PeakFQ assessment (1995-2015) compared to what the USACE 2003 generated (Table 7). These changes in flood frequencies have implications for documents such as the Hydrogeomorphic (HGM) report of the Middle Mississippi River Regional Corridor completed in 2008, which uses figures to delineate habitat compatibility based on land surface elevation. Based on USGS peak gage height (ft) data, a greater than or equal to two-year flood occurred at least once per year from 2008 to 2016, except in 2012 (drought year). A greater than or equal to five-year flood happened at least once in 2008, 2011, 2013, 2015, and 2016. Additionally, a greater than or equal to 10-year and 20-year flood both occurred in 2016. This data shows that more recently there are greater occurrences of flood events.

Although no trend in annual peak streamflow of the Mississippi River was identified at the Chester, IL gage (1926-2015), assessed flood frequency data showed a more frequent occurrence of flood events in that stretch of the River. Interpretation of hydrologic data in this region is challenging because the Mississippi River is a large system, there are many influences within the upstream drainage area, and a lot of tributaries feeding into the River that can alter its dynamics. From the data assessed, average annual discharge of the Mississippi River at Chester, IL has significantly increased since the 1940s.

U.S. Historical Climatology Network data for Sparta, IL (1950-2014) showed a significant increase in average water year temperatures and a slight increase in average water year total precipitation. Average yearly temperatures have increased across all seasons. Although not significant, there was a slight increase in total precipitation between October and March.

Winters and springs are expected to be wetter by the end of the century, while less precipitation is expected during the summer. This could not only increase the chance of flooding during specific times of the year, but also increase the possibility of droughts during the summer (UCS 2009). Average summer temperatures in Missouri and Illinois are expected to increase by more than 3°F in the next few decades and by about 13°F toward the end of the century (UCS 2009). In addition, projections for the Midwest show that the occurrence of temperatures below freezing are expected to decrease. The increases in precipitation and temperature could increase the rate at which invasive species, specifically Asian carp, can spread across the area.

Agriculture is the predominant land use in the area, and erosion and runoff from these lands exposes some divisions of the Refuge more than others to fertilizers, herbicides, and pesticides. Particularly, agricultural land borders the northern side of Horse, Meissner and Harlow Islands. Additionally, Horse, Crains, Rockwood, and Wilkinson Islands all have private in holders that border or surround those divisions with crop fields.

The presence of levees separate nearby agricultural land from the River thus blocking natural movement of water across the floodplain, resulting in loss of floodplain habitat. Divisions that are exposed to the River experience greater flood frequencies and are subject to increased sedimentation and pollution due to the constricted floodplain. In contrast, those divisions that are blocked from the River by levees can become too dry because they are isolated from the River or too wet because the levees prevent natural drainage. All alterations have affected the type and quality of habitat available and impacted organisms residing in the area, specifically native fish and mussel populations.

With the present frequency, timing, and sediment loads associated with flood events, the habitat types on many divisions are converting to riverfront forest communities; primarily a monoculture of eastern cottonwoods (*Populus deltoides*) and black willows (*Salix nigra*). This may be desirable in certain areas but a larger amount of diverse habitat is ideal for restoration and establishment of key species.

Future changes in flow frequencies, magnitudes, and inundation depths of the MMRNWR floodplain are likely, in which case management could face increased difficulties in maintaining river-floodplain connections.

Since long, continuous tracts are ideal for large-scale river restoration and habitat protection, MMRNWR has a limited ability to restore “natural” flows and floodplain connectivity of the Mississippi River due to its fragmented nature. In addition, the Refuge also has limitations with new land acquisitions in the region, making effective restoration challenging.

Anthropogenic influences to the River and surrounding floodplain have changed or destroyed various habitat types. In turn, the presence and abundance of fish, wildlife, and other aquatic organisms have been altered. Native mussel and fish populations, including catfish, sunfish, and bass have decreased since the early 1900s (Duyvejonck 1996). In addition, the introduction of non-native fish species such as grass, common, and bighead carp have had a negative effect on native fish populations (Koel et al. 2000).

1.2 Recommendations

Middle Mississippi River National Wildlife Refuge lies in a dynamic system controlled by actions of the Mississippi River. Becoming increasingly relevant is the impact of climate change as a driving force affecting the surrounding area, as well as the nature of the river. These realities make it difficult to propose many realistic management actions. However, below are a handful of recommendations that may be useful in addressing the issues MMRNWR faces today and may face in the future.

Sediment deflection berms are being considered for Harlow, Crains, and Wilkinson Islands. The hope is these would divert sediment downriver, decreasing deposition, and allowing for the eventual development of a soil type more adequate for producing a higher diversity of vegetation and tree species, in particular pecan, the only hard mast-producing tree presently found on MMRNWR lands. As mentioned previously, the increased sedimentation rates observed on the Refuge have leveled lands decreasing topographic variation and depositing sand over much of the Refuge divisions. This has led to the establishment of monocultures of black willow and eastern cottonwood stands that are dominating the current landscape, decreasing diversity in species and forest structure.

Staff plate gages should be installed in key wetlands within each division, surveyed to mean sea level, and correlated to the U.S. Geological Survey (USGS) Chester gage.

Efforts to acquire and restore other lands within the floodplain should be pursued. Specifically, areas with higher elevations and greater topographic heterogeneity, larger tracks, and lands that can be hydrologically connected with the River should be prioritized. If more floodplain land surrounding Refuge divisions is purchased this could lead to the restoration of more historic floodplain habitat. Restoration of this habitat could allow for a wider variety of species to inhabit the area and bring back species, such as swamp rabbits, that once used this area for breeding, feeding, and overwintering ground.

Since flooding is one of the primary factors affecting the hydrology, habitat types, and surrounding landscape of the Refuge, it would be beneficial to monitor/assess/document annual flood frequencies, flood duration, and water levels above a certain height to have a better understanding of what occurred in the past, what is presently occurring, and what may occur in the future. This can be done using annual discharge data from the Mississippi River gage at Chester, IL, along with periodic readings of water surface elevations within each tract and bathymetry/topography surveys where necessary. In addition to monitoring this data, it would be useful to generate flood inundation maps for each division. In conjunction with the HREP project with U.S. Army Corps of Engineers (USACE), flood inundation maps will be produced for Harlow, Crains, and Wilkinson Islands. Water resources staff from the Division of Natural Resources and Conservation Planning can assist in developing flood inundation maps for all the Refuge divisions as a follow up effort to the MMRNWR WRIA.

Refuge management is concerned with increased sediment deposition in some areas of the Refuge. If possible, it would be beneficial to use sediment deposition models to give an idea where this may occur on the Refuge based on river flows.

Chapter 2: Introduction

Middle Mississippi River National Wildlife Refuge is located along the 'free-flowing' portion of the Mississippi River in Missouri and Illinois. The current acquisition boundary of the Refuge spans 195 river miles between the confluence with the Missouri River to the north and the Ohio River to the south. This same 195 miles of the Mississippi River is known as the Middle Mississippi River Regional Corridor (MMRRC). In this section of the Mississippi River, much of the floodplain is protected by levee systems, however MMRNWR is primarily located between the river and the levees. This is the first refuge downriver of the lock and dam system. The nearest and most southern lock and dam on the River is located in Granite City, IL and Glasgow Village, MO, respectively (just north of Saint Louis, MO). The Refuge was established in 2000 and is comprised of seven different divisions, totaling 8,074 acres (Figure 1).

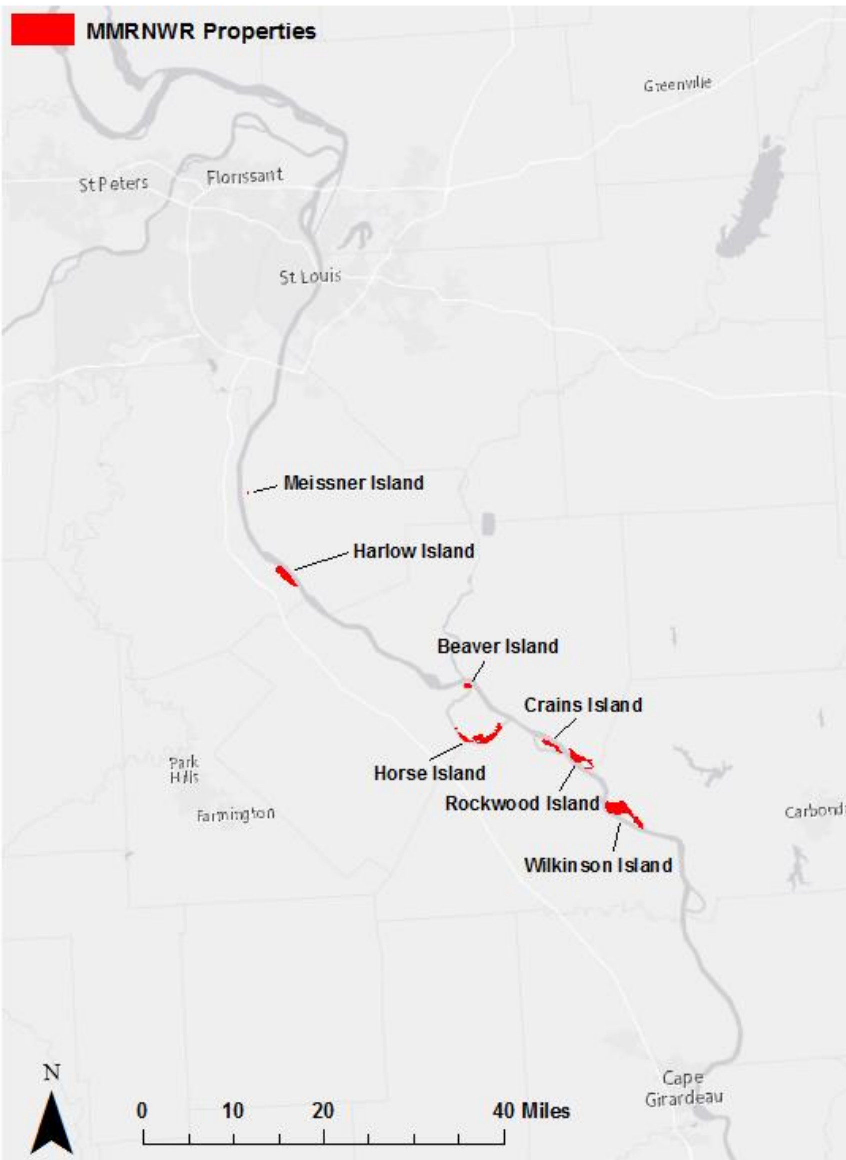

Figure 1: MMRNWR Properties

Middle Mississippi River National Wildlife Refuge divisions were established under mandates from five legislative authorities; the National Wildlife Refuge System Administration Act, the Refuge Recreation Act, the Emergency Wetlands Response Act of 1986, the Migratory Bird Conservation Act, and the Fish and Wildlife Conservation Act.

Since there are no water control structures and limited immediate levee protection, the Refuge has the ability to improve and restore floodplain connectivity with the Mississippi River that has previously been lost due to river navigation maintenance, flood protection, and land use change. Management of the Refuge is greatly impacted by the nature of the Mississippi River. Extended wet or dry periods, or extreme flood events can drastically influence Refuge habitats.

A wide range of habitat types are found on the Refuge, including floodplain forests, riverfront forests, marshes, swamps, sand bars, mudflats, chutes, swales, side channels, and open water. Together, these are important for sustaining a wide variety of terrestrial and aquatic species. More than 200 different species of birds pass through the area during fall and spring migrations, and many utilize Refuge habitat through winter and summer months, as well. Species that are particularly sensitive to the Refuge's water resources include the Pallid Sturgeon and Least Tern, both of which are federally-listed endangered species in the Mississippi River. While pallid sturgeons have shown evidence of natural reproduction in the area, their habitat has been highly degraded due to river channelization (USFWS 2016). Populations of Least Terns have increased along this reach of the Mississippi River. This is assumed to be the result of immigration, and not reproductive productivity. Destruction and elimination of Least Tern nesting habitat is the primary cause of their reproduction decline. Other causes include human disturbance and pollutants (USFWS 2016). Since MMRNWR provides some of the only existing habitat Least Terns require for nesting, hydrologic processes and habitat management of this area are critical to their success.

3. Natural Setting

The natural setting section describes the abiotic resources associated with the refuge, including relevant watershed boundaries, topography, soils, and climate. These underlying, non-living components of an ecosystem provide the context on which water resources are constructed and managed. Many of these elements are also described in the CCP (USFWS 2004).

Land and water use practices upstream of the Refuge all play a role in the form and function of habitats within MMRNWR, while local practices and infrastructure result in more direct effects to refuge habitats. Middle Mississippi NWR is located at the bottom of two large watersheds, the Missouri River and the Upper Mississippi River. Since the Refuge lies just below the confluence of two of the largest rivers on the continent it is therefore influenced by the higher sediment loads and regulated water of the Missouri River to the west, and by the Upper Mississippi River that is prone to seasonal flooding and is a transporter of agricultural land pollutants. Middle Mississippi River NWR seems to be affected by basin wide as well as local impacts, neither of which the Refuge has much control over.

Over the last century navigation, dams, levees, reservoirs, navigation pools, channel straightening, and bank stabilization have altered the hydrology of the Mississippi River. These changes have influenced fish migration, interrupted flow patterns, and have affected the transport and distribution of water and sediments. Within the Mississippi River along MMRNWR, structures have been placed to narrow channel width in an effort to improve navigation. In addition, a 9-foot channel was dredged, and is currently maintained for low water navigation. Maintenance of this navigational channel has resulted in the degradation of island and side channel habitats, which are important for high flow refuge for fish, as well as stopover ground for migratory birds (USFWS 2013). Primarily in the lower portion of the Mississippi River levees have been built to protect urban and agricultural areas from flooding. Levee construction has significantly reduced the natural floodplain of the river. Levees have reduced the area of seasonally flooded wetlands, resulting in fewer backwater habitats (Mississippi River Water Quality and the Clean Water Act: Progress, Challenges, and Opportunities – http://www.nap.edu/catalog/12051.html).

Land use in the Mississippi River basin has changed dramatically over the past couple centuries. Vast areas of prairie and forest have been converted into agricultural and urban lands. In addition, more than half of the original wetland ecosystems have been transformed to other land uses (Mississippi River Water Quality and the Clean Water Act: Progress, Challenges, and Opportunities – http://www.nap.edu/catalog/12051.html).

Significant water quality problems in the Mississippi River watershed stem from these industrial and landscape developments (Turner and Rabalais 2003). Wetlands are crucial in regulating and reducing runoff of pollutants. The conversion of these lands primarily into agricultural fields has reduced the natural buffering system that can help reduce toxins and nutrients entering the Mississippi River mainstem and tributaries (Mississippi River Water Quality and the Clean Water Act: Progress, Challenges, and Opportunities – http://www.nap.edu/catalog/12051.html).

These landscape changes have resulted in significant loss of habitat in many areas of the Mississippi River basin, including the region encompassing MMRNWR. As habitat within MMRNWR has changed, fish, wildlife, and other aquatic organism populations have been altered. The introduction of non-native fish such as bighead, silver, and grass carp, have also negatively impacted native fish populations (Koel et al. 2000). The loss of wetland habitat has likely caused reductions in reptile and amphibian species, as well (Duyvejonck 1996, Smith 1996).

Despite the anthropogenic disturbances, MMRNWR land that was formerly in row crop production has started to return to an early successional forest state. This is the result of the Refuge's continued work in enhancing and restoring historic floodplain habitats.

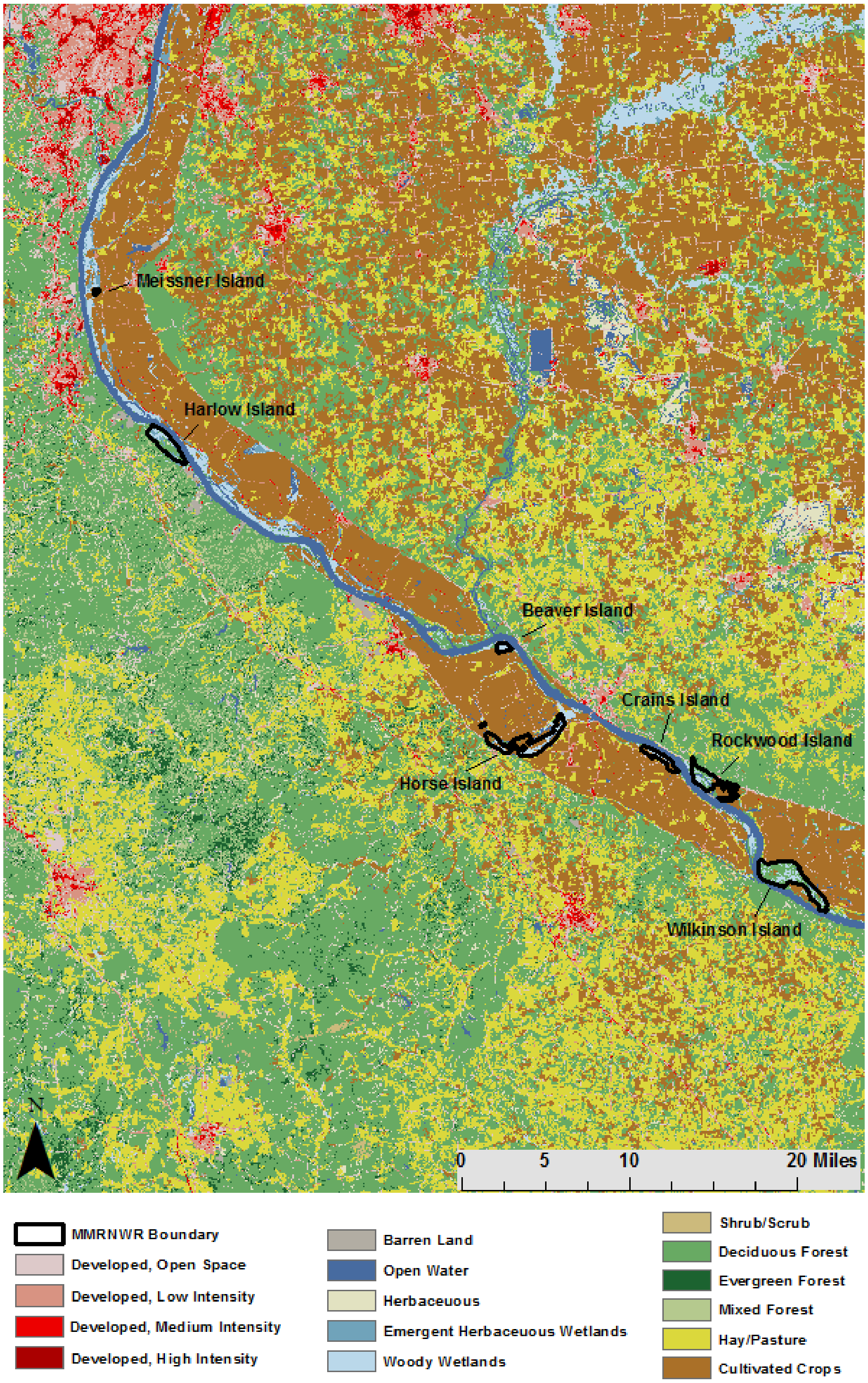

Figure 2: Map of land cover types surrounding MMRNWR (2011)

3.1 Hydrologic Unit Codes (HUCs)

Hydrologic information can be described in the context of MMRNWR's designated Region of Hydrologic Influence (RHI), which is the relevant region for the collection of water quality and quantity information. For the purposes of the WRIA, Hydrologic Unit Code (HUC) boundaries, part of the USGS Watershed Boundary Dataset, are often used as a general framework to designate RHIs. HUCs designate watersheds of various sizes and often represent the initial aggregate level of water quality and quantity information available from a variety of agencies. HUC boundaries are a successively smaller classification system based on drainage, adapted from Seaber et al. (1987). The 8-digit HUCs (HUC-8s) most relevant to MMRNWR's authorized boundary include the Cahokia-Joachim and the Upper Mississippi-Cape Girardeau (Figure 3). Also, maps and information for relevant HUC-10s and the smaller HUC-12 boundaries are provided below (Table 1).

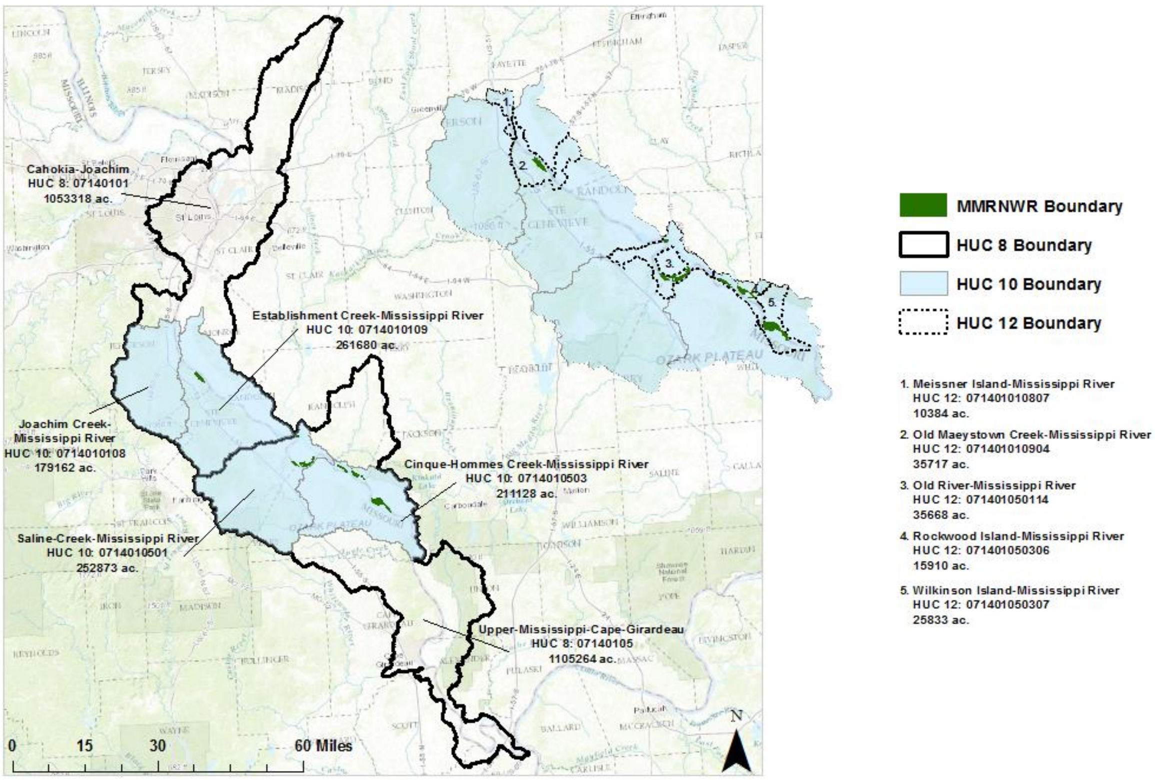

Figure 3: Hydrologic Unit Codes corresponding to MMRNWR properties

HUC12	Name	Area (acres)
071401050306	Rockwood Island-Mississippi River	15910
071401010807	Meissner Island-Mississippi River	10384
071401050307	Wilkinson Island-Mississippi River	25833
071401050114	Old River-Mississippi River	35668
071401010904	Old Maeystown Creek-Mississippi River	35717
HUC10	**Name**	**Area (acres)**
0714010503	Cinque Hommes Creek-Mississippi River	211128
0714010109	Establishment Creek-Mississippi River	261680
0714010108	Joachim Creek-Mississippi River	179162
0714010501	Saline Creek-Mississippi River	252873

HUC8	Name	Area (acres)
07140101	Cahokia-Joachim	1053318
07140105	Upper Mississippi-Cape Girardeau	1105264

Table 1: Hydrologic Unit Codes and areas relevant to MMRNWR acquired divisions

Middle Mississippi River National Wildlife Refuge's RHI is primarily represented by the 10-digit Hydrologic Unit Code (HUC-10) boundaries. While these represent tributary drainages flowing into or near the Refuge, the majority of the Mississippi River Basin, especially the Upper Mississippi and Missouri River watersheds (Figure 4), is important to consider while conducting water resource assessments for the Refuge. This is because the River's water levels and water quality primarily control MMRNWR's ecological health. Some portions of the Mississippi River watershed, specifically where the Ohio River meets the Mississippi River, are not relevant to MMRNWR's RHI. For this report, surface water quantity and quality monitoring sites were assessed in the Mississippi River mainstem.

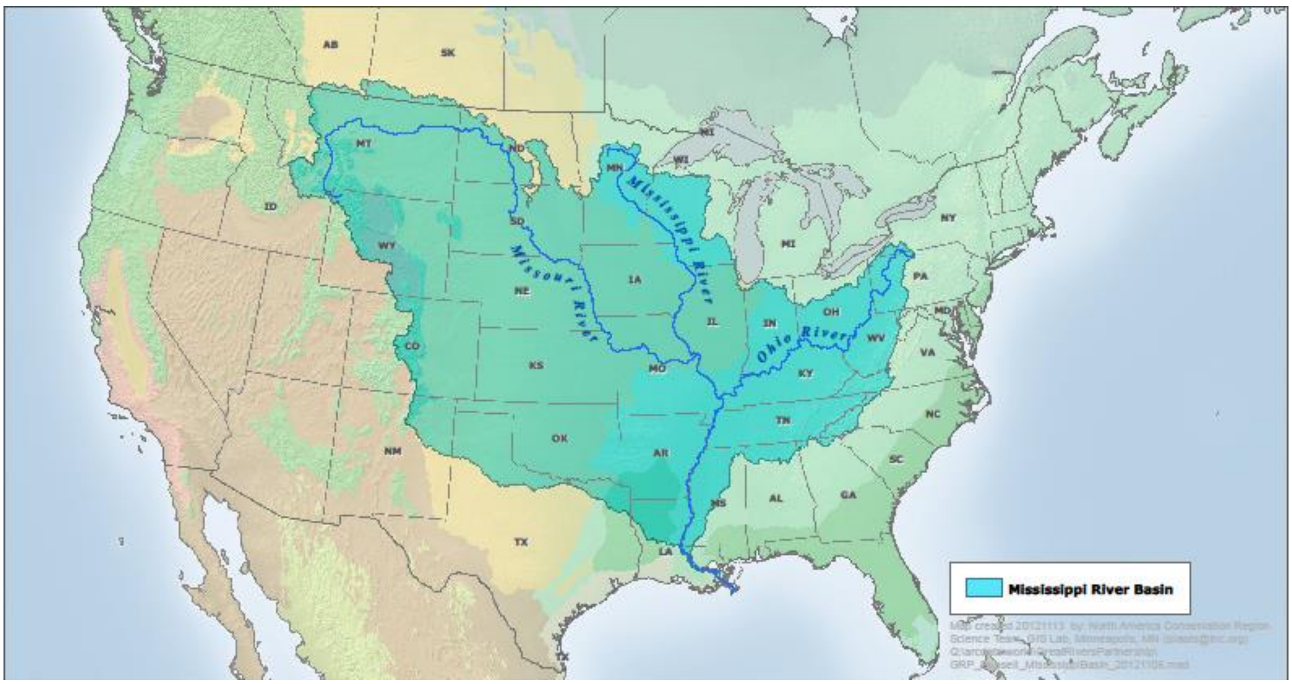

Figure 4: Map of the Mississippi River Basin (Source Credit: http://www.greatriverspartnership.org/en-us/northamerica/Mississippi/pages/default.aspx)

3.2 Topography

High resolution (1-meter) bare-earth LiDAR data is currently available for MMRNWR's property divisions, processed by Capeder (2016) and collected in 2012. Topographic maps for each division can be found in Appendix A.

3.3 Soils

Detailed soils data is available at the HUC-8 level through the Soil Survey Geography (SSURGO) Database, and can be accessed through the ArcGIS SSURGO data downloader (http://www.arcgis.com/apps/OnePane/basicviewer/index.html?appid=a23eb436f6ec4ad6982000dbaddea5ea). Soil drainage class information for relevant areas of the Refuge are reported in Appendix B. For most of the Refuge area, soil drainage ranges from poorly drained to well drained. Also, numerous additional datasets related to soils, hydrology, and climate such as soil taxonomic class, water table depth, and average temperature data are included in the SSURGO data package.

3.4 Long Term Climate Trends

Executive Order 13653 (2013) calls for "strengthened resilience to climate change impacts." Agencies are instructed to prepare for climate change effects that will continue to be felt by revising policies and programs appropriately, and specifically to identify alterations to be made to land and water-related regulations and programs. Executive Order 13653 directs agencies to encourage the function of natural storm buffers, such as wetlands, and to provide relevant information about climate change to the public so decisions can be made with careful consideration for future impacts. Additionally, agencies need to develop and implement procedures for the identification and management of the most serious threats.
The WRIA provides a preliminary broad-based analysis of trends and patterns in precipitation and temperature. Climate is defined here as the typical precipitation and temperature conditions for a given location over years or decades. These types of trends and patterns affect groundwater levels, river runoff, and flooding regularity and extent. This section evaluates MMRNWR's current and historical climate patterns.

Climate Change Projections

Several reports indicate that the Midwest in general has already been affected by climate change. For example, heavy precipitation events are currently much more frequent and intense in the region than they were a century ago (Kunkel 1999, Kunkel et al. 2003, Kunkel et al. 2013), and the Midwest has experienced an increase in runoff, with expectations of more intense flood conditions in the future (Johnson et al. 2013). Already at high flood risk, winters and springs are expected to be about 20% wetter toward the end of the century (UCS 2009). While average winter precipitation across the Midwest is expected to increase, summer precipitation is projected to remain the same or decrease (Wuebbles and Hayhoe 2003).

Toward the end of the century Illinois and Missouri could see upwards of 100 days per summer with temps over 90°F and approximately 30 days over 100°F. In Illinois under a higher-emissions scenario, average summer temperatures are expected to increase by more than 3°F in the next few decades and by about 13°F toward the end of the century (UCS 2009). This, coupled with reduced precipitation during the summer could lead to reductions in soil moisture, causing drought-like conditions. Not surprisingly, the occurrence of temperatures below freezing are expected to decrease. Projections for the Midwest show that by mid-century about 15 fewer days will experience minimum temperatures below freezing (http://glisa.umich.edu/media/files/NCA/MTIT_Future.pdf0).

Climate Conditions Derived from PRISM and USHCN Datasets

Weather information was obtained from the PRISM Climate Group at Oregon State University (http://prism.oregonstate.edu/). The PRISM interpolation method provides spatial climate information for the conterminous United States, partially based on data from approximately 13,000 precipitation and 10,000 temperature stations. The dataset for temperature and precipitation is interpolated from nearby weather stations and corrected for elevation, enabling point estimation. Datasets were collected for parcels corresponding to Meissner Island, Harlow Island, Beaver Island, Horse Island, Crains Island, Rockwood Island, and Wilkinson Island. See below Table 2 and Figures 5 and 6. In summary:

- Based on the PRISM interpolation, average monthly temperatures (1940-2014) across the divisions ranged from 31.9 °F in January to 78.5 °F in July.
- Based on the PRISM interpolation, average monthly precipitation totals (1940-2014) are very similar across all divisions. Precipitation totals increase throughout late winter, early spring, peaking in May (4.7 inches) and then gradually tapering off through mid-winter.
- Average annual temperatures increased slightly with distance downstream. The coolest temperature was at Meissner Island (55.5 °F) and the warmest was at Wilkinson Island (56.8 °F).
- Average annual precipitation totals increased slightly with distance downstream. The lowest total precipitation was at Harlow Island (39.7 inches) and the highest total precipitation was at Wilkinson Island (43.2 inches).

Unit	Month	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec	Average Annual (1940-2014)
Meissner Island (Lat: 38.2874 Lon: -90.3762 Elev: 427ft)	Average Monthly Precipitation (inches) (1940-2016)	2.2	2.3	3.6	4.1	4.5	4.1	3.5	3.2	3.4	2.8	3.5	2.9	39.9
	Average Monthly Temperature (degrees F) (1940-2016)	30.8	34.9	44.5	56.4	65.2	74.0	78.0	76.4	68.5	57.6	45.5	34.9	55.5
Harlow Island (Lat: 38.1654 Lon: -90.2909 Elev: 400ft)	Average Monthly Precipitation (inches) (1940-2016)	2.2	2.3	3.6	4.0	4.5	4.0	3.5	3.2	3.3	2.9	3.5	2.9	39.7
	Average Monthly Temperature (degrees F) (1940-2016)	31.2	35.1	44.8	56.4	65.3	74.2	77.9	76.2	68.6	57.8	45.7	35.2	55.7
Beaver Island (Lat: 37.9604 Lon: -89.9075 Elev: 387ft)	Average Monthly Precipitation (inches) (1940-2016)	2.2	2.3	3.6	4.0	4.8	4.0	3.7	3.3	3.3	2.9	3.6	3.0	40.5
	Average Monthly Temperature	32.1	35.9	45.2	57.0	66.4	75.3	79.0	77.1	69.6	58.6	46.4	35.9	56.5

	(degrees F) (1940-2016)													
Horse Island (Lat: 37.8829 Lon: -89.9062 Elev: 390ft)	Average Monthly Precipitation (inches) (1940-2016)	2.2	2.3	3.6	4.0	4.5	4.0	3.5	3.2	3.3	2.9	3.5	2.9	41.8
	Average Monthly Temperature (degrees F) (1940-2016)	32.1	36.0	45.2	57.0	66.2	75.2	78.8	77.1	69.5	58.5	46.2	36.0	56.5
Crains Island (Lat: 37.8715 Lon: -89.7517 Elev: 499ft)	Average Monthly Precipitation (inches) (1940-2016)	2.5	2.6	4.0	4.2	5.0	4.2	3.7	3.3	3.4	3.0	3.8	3.2	42.5
	Average Monthly Temperature (degrees F) (1940-2016)	32.2	36.1	45.3	56.8	65.8	74.7	78.3	76.8	69.2	58.3	46.3	36.1	56.3
Rockwood Island (Lat: 37.8379 Lon: -89.7050 Elev: 348ft)	Average Monthly Precipitation (inches) (1940-2016)	2.6	2.7	4.1	4.3	4.9	4.1	3.6	3.3	3.4	3.0	3.8	3.2	42.7
	Average Monthly Temperature (degrees F) (1940-2016)	32.2	36.2	45.4	57.0	66.1	75.0	78.5	76.8	69.4	58.3	46.4	36.1	56.5
Wilkinson Island (Lat: 37.7565 Lon: -89.6301 Elev: 361ft)	Average Monthly Precipitation (inches) (1940-2016)	2.7	2.8	4.3	4.4	4.8	4.1	3.5	3.4	3.2	3.0	3.9	3.4	43.2
	Average Monthly Temperature (degrees F) (1940-2016)	32.5	36.5	45.7	57.5	66.5	75.3	78.8	77.2	69.8	58.7	46.7	36.4	56.8
All Units Listed Above	Average Monthly Precipitation (inches) (1940-2016)	2.4	2.5	3.8	4.2	4.7	4.1	3.6	3.3	3.3	3.0	3.7	3.1	41.4
	Average Monthly Temperature (degrees F) (1940-2016)	31.9	35.8	45.2	56.9	65.9	74.1	78.5	76.8	69.2	58.3	46.2	35.8	56.2

Table 2: Monthly and annual precipitation and temperature for Refuge divisions (PRISM)

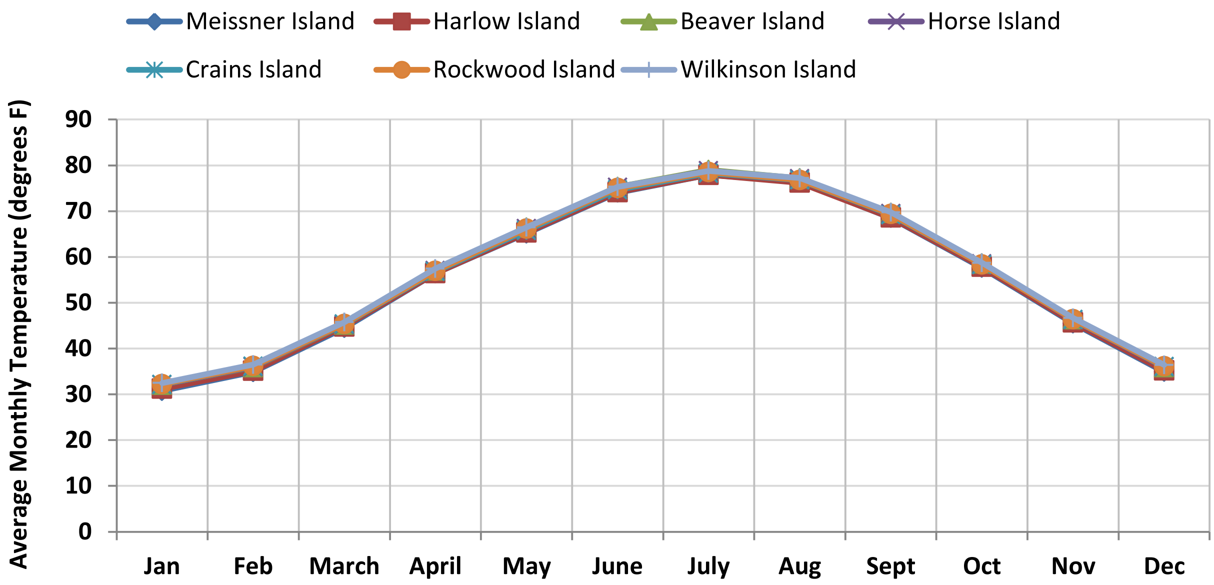

Figure 5: Monthly temperature data for Refuge divisions (PRISM-derived) (1940-2014)

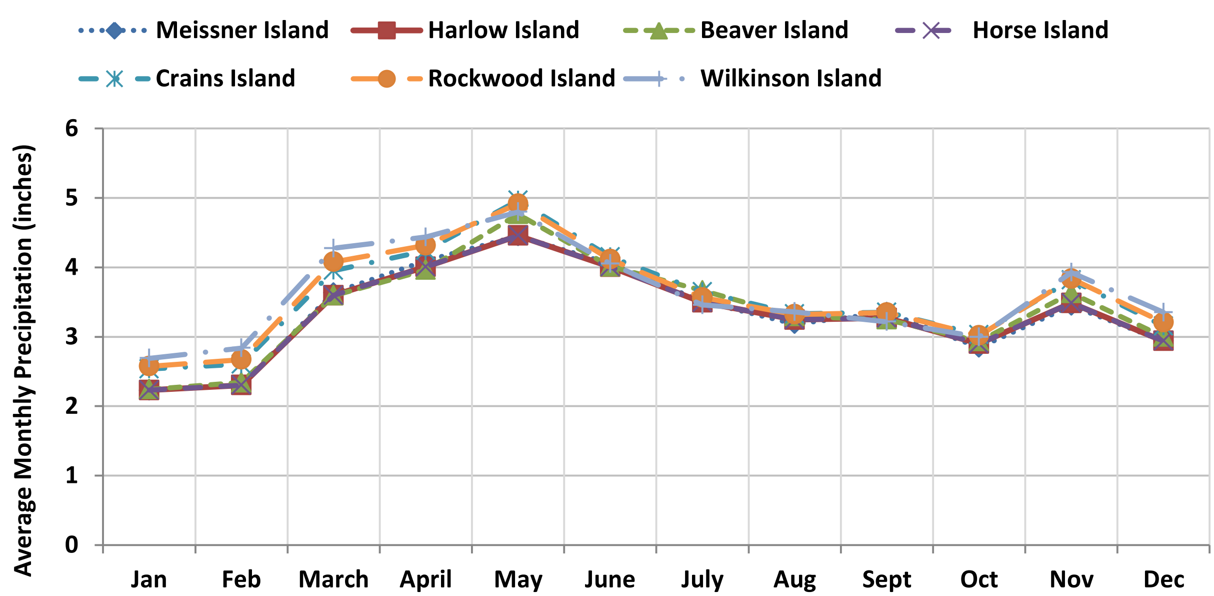

Figure 6: Monthly precipitation data for Refuge divisions (PRISM-derived) (1940-2014)

Climate data was also obtained from the U.S. Historical Climatology Network ([USHCN]; http://cdiac.ornl.gov/epubs/ndp/ushcn/ushcn.html; Menne et al. 2012). The USHCN is a network of sites listed by the National Weather Service, which maintains standards in quality and continuity of data collection.

The USHCN station at Sparta, IL (118147) was evaluated to assess climate trends in areas representative of Refuge lands. Average water year temperature and precipitation graphs from this site are shown below (Figures 7 & 8). While these datasets provide insight to local weather patterns, the Mississippi River Basin's hydrology is complex and is strongly dictated by climate patterns across a broader scale. For more USHCN climate data see Appendix E. The main findings from a brief evaluation of these USHCN datasets are summarized below:

- There was a significant increase in average water year temperatures (p=0.002).
- Average yearly temperatures (1950-2014) have increased across all seasons with the greatest increase occurring during the cool season (Oct-March) and spring.
- There was a significant increase in average mean spring temperatures (p=0.001), minimum spring temperatures (p<0.001), and maximum spring temperatures (p=0.014). There was also a significant increase in minimum summer temperatures (p<0.001).
- Average mean (p=0.017) and minimum (p<0.001) cool season temperatures have increased significantly since the 1950s.
- Although not significant, there was a slight increase in total precipitation during the cool season (October-March) (1950-2014).

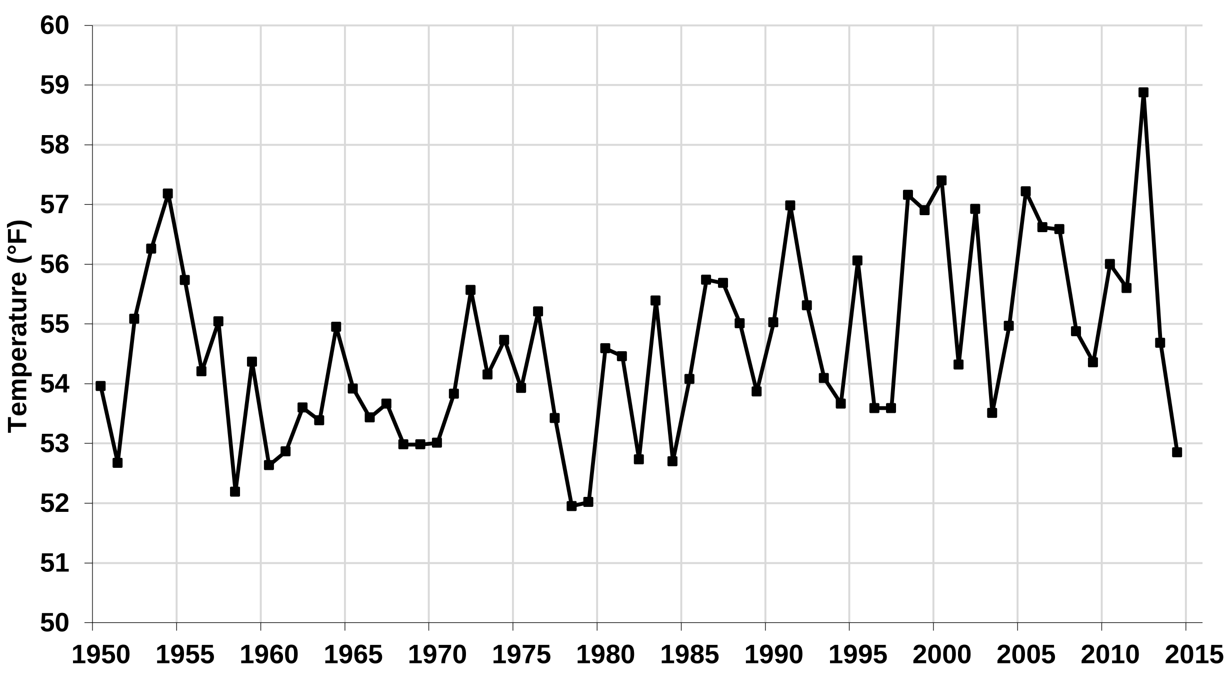

Figure 7: Average water year temperatures Sparta, IL (1950-2014)

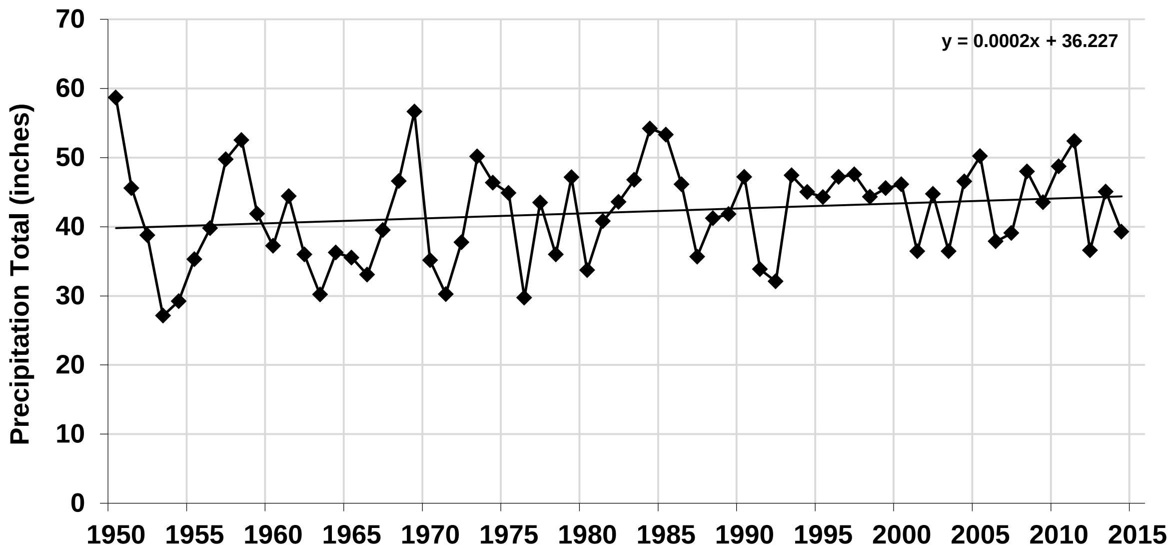

Figure 8: Average water year precipitation Sparta, IL (1950-2014)

Hydroclimatic Data Network

Reference hydrographs obtained from the Hydro-Climatic Data Network (HCDN) provide additional context for the assessment of surface water quantity patterns. The HCDN is a network of USGS stream gages located within relatively undisturbed watersheds, which are appropriate for evaluating trends in hydrology and climate that are affecting flow conditions (Slack et al. 1992, Lins 2009). This network attempts to provide a look at hydrologic conditions without the confounding factors of direct water manipulation and land use changes. Average annual discharge and annual peak streamflow trends were compared for this analysis for two HCDN gages on tributaries to the Mississippi River, including USGS 05595200 Richland Creek near Hecker, IL and USGS 07018100 Big River near Richwoods, MO.

Average annual discharge and annual peak streamflow have increased at both stations, statistically significant trends were observed at Richland Creek (average annual discharge: $p=0.013$; peak streamflow: $p=0.038$). Trends at Richland Creek exhibit average monthly discharge increases through parts of the year (March-May), and decreases in others (September and October) (Figure 9). This suggests that some areas may have experienced hydroclimate changes on a seasonal basis. Even though some of these smaller river drainages are experiencing hydroclimatic changes, hydrologic trends due to climate changes in the Mississippi River are far more influential. This is the case today because MMRNWR is for the most part passively managed and the impacts on the Refuge are a direct result of the nature of the Mississippi River.

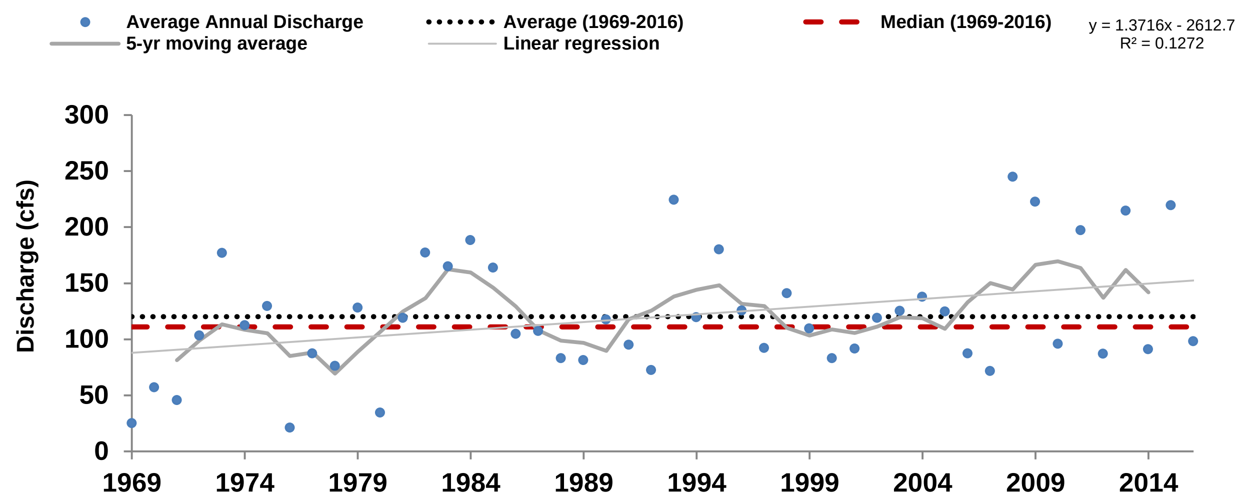

Figure 9: Average annual discharge for Richland Creek (USGS 05595200) (1969-2016)

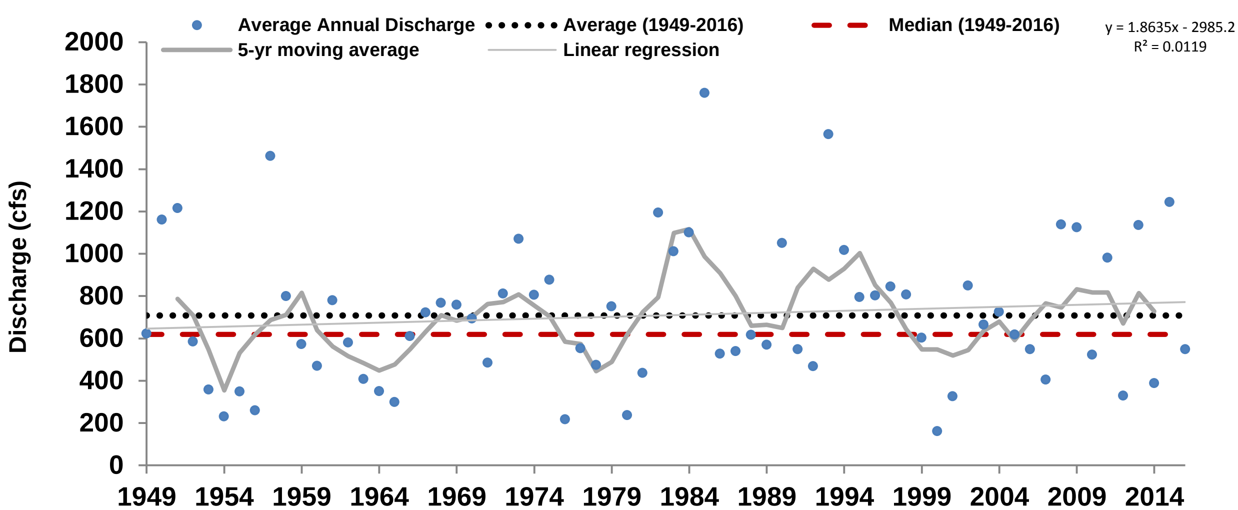

Figure 10: Average annual discharge for Big River (USGS 07018100) (1949-2016)

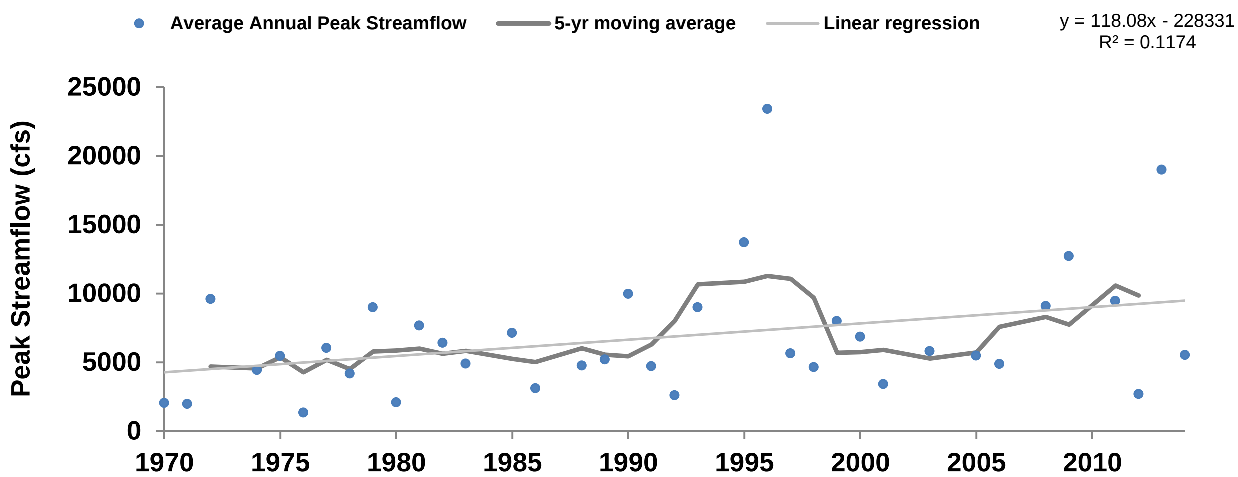

Figure 11: Average annual peak streamflow for Richland Creek (USGS 05595200) (1970-2014)

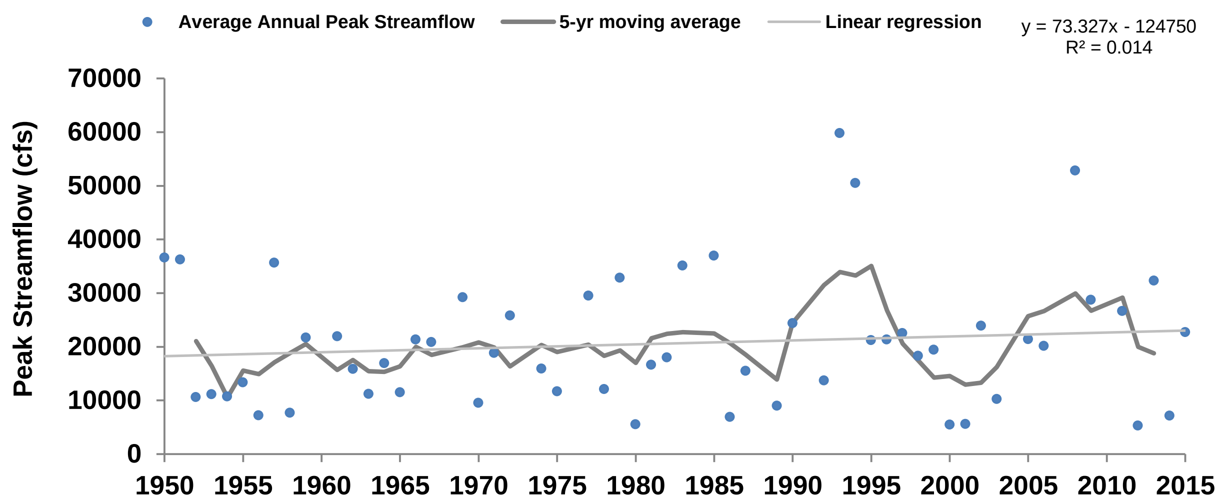

Figure 12: Average annual peak streamflow for Big River (USGS 07018100) (1950-2015)

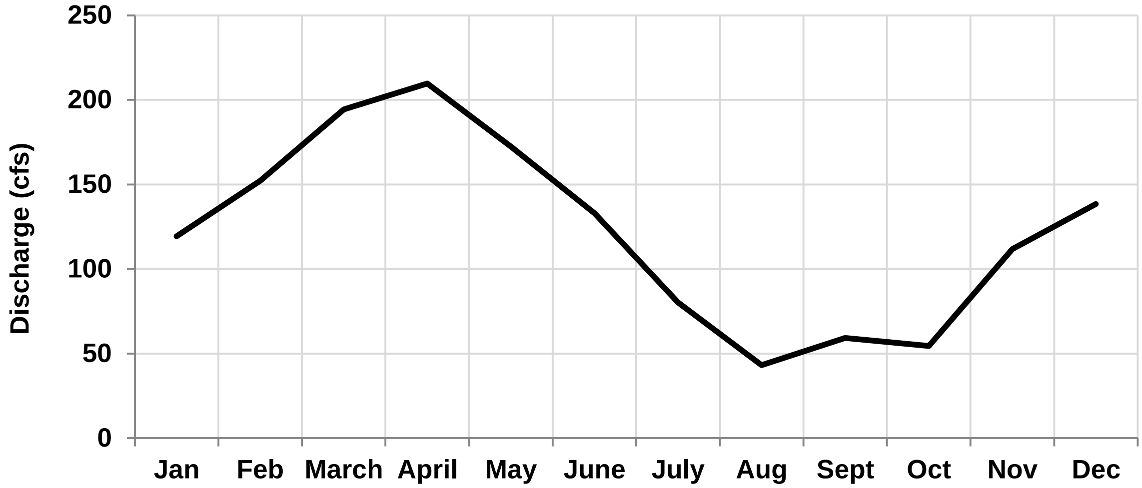

Figure 13: Average monthly discharge for Richland Creek (USGS 05595200) (1970-2016)

Chapter 4: Water Resource Features

4.1 Management Divisions

The primary purpose of the Refuge is to provide suitable habitat for a wide variety of birds and aquatic organisms, and to restore the ecological integrity of the floodplain by increasing connectivity with the Mississippi River. Currently, MMRNWR manages seven divisions, totaling 8,074 acres (Table 3) and none involve active water level or moist soil management.

Division	Acres	River Miles
Meissner Island	78	153.5-155.5
Harlow Island	1224	140.5-144
Beaver Island	245	116-118
Horse Island	2110	111-117
Crains Island	553	104-107
Rockwood Island	1224	99-104
Wilkinson Island	2640	88.5-93
Total	8074	

Table 3: MMRNWR management divisions, acreage, and river miles

Meissner Island

Meissner Island is comprised of unleveed land open to river flooding. There is an agricultural levee just east of the division. On the west side of the Island lies “Lucas Slough,” a side channel partially filled with sediment. Floodplain forest now covers the former cropland on the Island.

Harlow Island

The majority of this Island was cropland protected by a levee which was breached during the flood of 1993. The levee was left unrepaired to allow for river and floodplain connectivity. Floodplain forest now covers the former cropland on the Island.

Beaver Island

This piece of land is a true island consisting of an active side channel, many secondary channels, and cottonwood forest. Several pallid sturgeon have been caught in the vicinity of the island.

Horse Island

This Island is not protected by levees and is located at the end of the abandoned former Mississippi River channel. It consists of riverfront forest, some of which was converted from agricultural land.

Crains Island

Crains Island is located on the river side of the levee in Missouri, where it frequently floods. It consists of active secondary side channels, riverfront forest, remnant oxbows, and sloughs.

Rockwood Island

Rockwood Island is subject to river flooding as it primarily consists of unleveed river bed. It is comprised of chutes, swales, bottomland lake habitat, floodplain forest, and riverfront forest. Union Pacific Railroad is north of the Island.

Wilkinson Island

An agricultural levee that protected the private in-holder's property at Wilkinson Island was breached in the 1993 flood and has not been repaired. Most of the Island consists of willow and cottonwood forest, but riverfront forest and remnant wet meadow are also present.

4.2 National Wetlands Inventory

The National Wetland Inventory (NWI) is an extensive, ongoing survey by the USFWS, of aquatic habitats across the United States. The NWI is based on interpretation of aerial photographs, not ground surveys, and its criteria differ somewhat from those used in jurisdictional wetland delineations for permitting by the United States Army Corps of Engineers under Section 404 of the Clean Water Act. Tables and maps detailing NWI data for MMRNWR are found in Appendix C.

4.3 National Hydrography Dataset

The National Hydrography Dataset (NHD) is a vector geospatial dataset including information about the nation's lakes, ponds, rivers, streams, and other water features that are part of the USGS's National Map. Within the divisions' boundaries, the flowpaths identified by the NHD can be broken down based on type. The majority of flowpaths were considered either stream/river features or artificial paths. Maps and a table of relevant NHD information for MMRNWR are provided in Appendix D.

The NHD provides an approximate representation of general water flow and does not necessarily reflect actual conditions. Further, the NHD's inventory of "named features" is not necessarily all-inclusive, and some of the flowlines may be mis-categorized.

Chapter 5: Water Resource Monitoring

The WRIA has identified historical and ongoing water resource related monitoring efforts on or near the Refuge. Ground and surface water stations were considered relevant if located within the Mississippi River floodplain or the Refuge boundary. Relevant sites were evaluated for applicability based on location, period of record, extensiveness of data, sampling parameters, trends, and dates of monitoring. Water resource datasets collected on the Refuge can be categorized as water quantity or water quality monitoring of surface or groundwater.

Water quantity monitoring typically involves measurements of water level and/or volume in a surficial water body or subsurface aquifer. Water quality can include laboratory chemical analysis, deployed sensors or biotic sampling such as fish assemblages or invertebrate sampling. Biotic sampling is often used as an indicator of biological integrity, which is a measure of stream purpose attainment by state natural resources management organizations. Potential water quality threats may be identified by comparing monitoring data with recommended standards.

5.1 Water Quality Criteria

The Environmental Protection Agency (EPA) developed technical guidance manuals and nutrient criteria for the protection of aquatic life in various types of waters specific to different ecoregions. Those developed for rivers/streams and lakes/reservoirs for ecoregion IX and ecoregion XI (borders close to the western edge of ecoregion IX and Refuge boundary) are summarized below (USEPA 2000; Table 4). These criteria are relevant to individual streams and lakes within MMRNWR's RHI, but do not necessarily apply to Refuge wetland divisions.

Additional information related to the application of federal water quality standards and regulations to wetlands is provided by the EPA's Water Quality Standards Handbook (http://water.epa.gov/lawsregs/guidance/wetlands/quality.cfm). Procedures outlined in this handbook are used when specific criteria for wetlands are developed.

Parameter	Ecoregion IX		Ecoregion XI	
	Rivers and Streams	Lakes and Reservoirs	Rivers and Streams	Lakes and Reservoirs
TP (ug/L)	36.56	20	10	8
TN (mg/L)	0.69	0.36	0.31	0.46
Chl *a* (ug/L)	0.93 (Spectrophotometric)	5.18 (Spectrophotometric)	1.61 (Spectrophotometric)	2.79 (Spectrophotometric)
Turb (FTU)	5.7	-	1.7	
Secchi (m)	-	1.53	-	2.86

Table 4: Nutrient criteria for rivers/streams and lakes/reservoirs established for ecoregion IX: Southeastern Temperate Forested Plains and Hills and ecoregion XI: Central and Eastern Forested Uplands (EPA 2000)

The EPA has compiled national recommended water quality criteria for roughly 150 pollutants to provide guidance in developing state-specific standards. The development of state and federal water quality standards requires consideration for the existing and potential uses of water bodies. Different uses often require different levels of protection for specific pollutants. Water bodies may have several different uses associated with them, such as aquatic life and recreation, in which case criteria for each pollutant are determined based on the most vulnerable designated use (https://www.epa.gov/wqc). Impairment listings for assessed waterbodies relevant to MMRNWR are discussed in the Surface Water Quality section.

5.2 Water Monitoring Stations and Sampling Sites

Several resources offer water quality and quantity datasets relevant to the Refuge and were utilized in the creation of MMRNWR's water monitoring site inventory. For example:

- Data for historical sampling locations can be retrieved through the EPA STORET (STOrage and RETrieval; http://www.epa.gov/storet) database. This data warehouse is a repository for water quantity, water quality, biological, and physical data used by state environmental agencies, EPA and other federal agencies, universities, and private citizens.
- Water quantity and quality data for active and inactive monitoring sites can also be accessed from the USGS National Water Information System (NWIS) database (http://www.waterqualitydata.us).
- There are several US Army Corps of Engineers (USACE) water monitoring stations in the Mississippi River mainstem as well as tributaries of the River (http://rivergages.mvr.usace.army.mil/WaterControl/new/layout.cfm). Three of these stations on the mainstem were identified as relevant to MMRNWR (Table 5). Although data was not gathered from these stations for this report, they are listed below as a reference for possible future use.

The WRIA identified and gathered data from three monitoring sites that are considered applicable to the Refuge's water resources, including one surface water monitoring site and two groundwater monitoring sites (see Figure 14 and Table 5 below). A list of inactive sites that are relevant, but not directly applicable to the resources of concern, was also created and will be loaded into the ECOS WRIA application (https://ecos.fws.gov/wria).

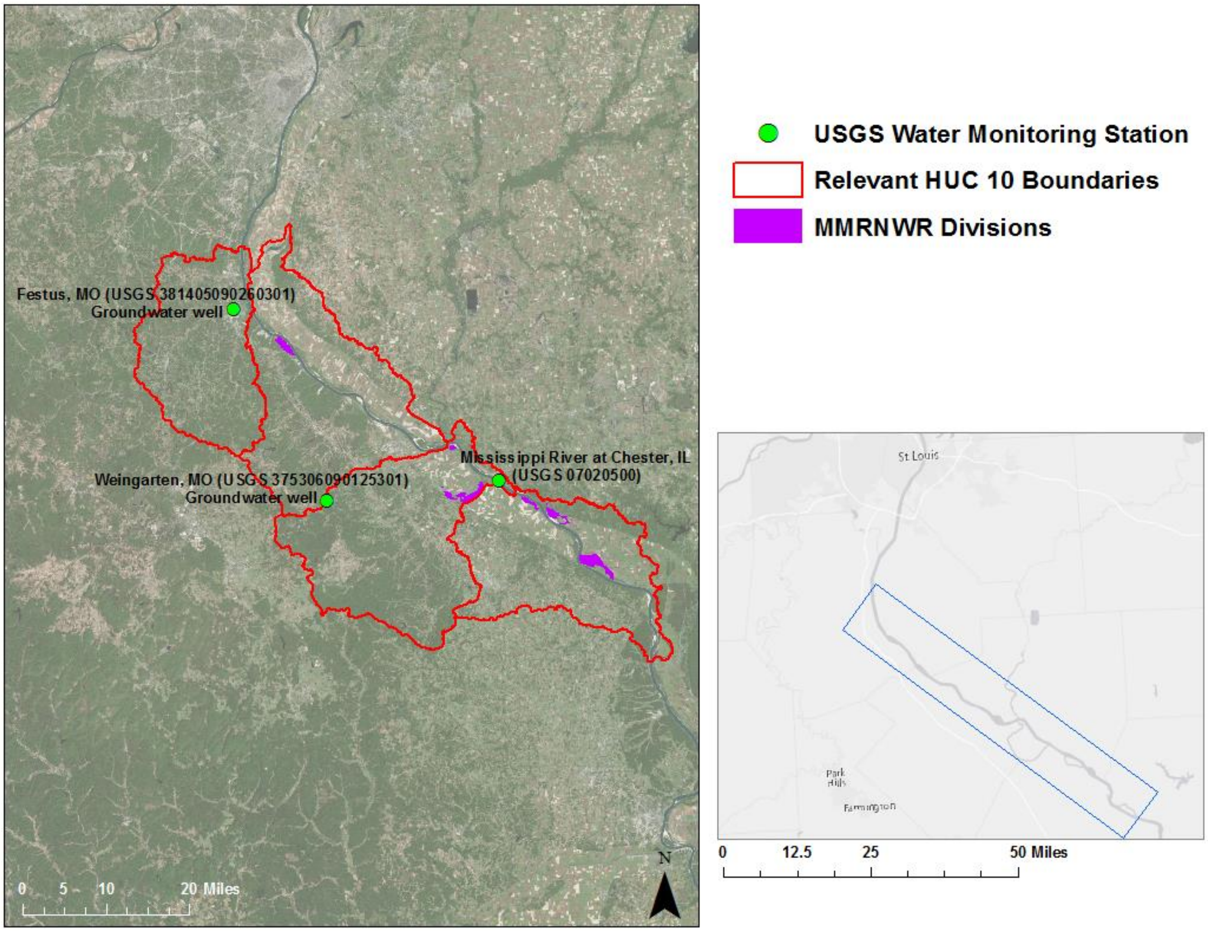

Figure 14: Relevant water monitoring locations (used to gather data for this report-bold in table below)

Site Name	ID and Link	Location	Elevation	Notes	Record maintained by:
Mississippi River at Chester, IL	USGS-07020500	Latitude 37°54'02.67" Longitude 89°49'48.76" NAD83	340.72 feet above NAVD88	Daily, monthly, and annual discharge/gage data (1942-present)	USGS Missouri Water Science Center
Festus	USGS-381405090260301	Latitude 38°13'26.5" Longitude 90°23'47.1" NAD83	450 feet above NAVD88	Daily depth to groundwater level (2002-present). Located on Mississippi River floodplain.	USGS Missouri Water Science Center
Weingarten	USGS-375306090125301	Latitude 37°53'06.1" Longitude 90°12'53.6" NAD83	857.7 feet above NAVD88	Daily depth to groundwater level (2009-present) Located on Mississippi River floodplain.	USGS Missouri Water Science Center
Mississippi River at Brickeys, MO	USACE-Mississippi River at Brickeys, MO	Latitude 38.08589433 Longitude -90.21053992	---	Period of record: 1891-2014 (in pdf archive http://mvs-wc.mvs.usace.army.mil/archive/mi/mibr/)	St. Louis District, Corps of Engineers
Mississippi River at Red	USACE-Mississippi River at Red Rock,	Latitude 37.73333333	---	Period of record: 1898-2012 (in pdf archive http://mvs-	St. Louis District,

Rock, MO	MO	Longitude - 89.650000000		wc.mvs.usace.army.mil/archive/mi/mirr/)	Corps of Engineers
Mississippi River at Grand Tower, IL	USACE-Mississippi River at Grand Tower, IL	Latitude 37.65774073 Longitude -89.51260635	---	Period of record: 1885-2014 (in pdf archive http://mvs-wc.mvs.usace.army.mil/archive/mi/migt/)	St. Louis District, Corps of Engineers

Table 5: Relevant water monitoring site information

5.3 Surface Water Quantity

Since the Mississippi River watershed is so large there are many influences that could impact surface water quantity. Changes in surface water quantity are evident over time at MMRNWR. Climate change, land-use change, and river engineering have contributed to statistically significant increases in flooding in the River over the last 100-150 years (Pinter et al., 2008). Agricultural practices, such as tile drainage, irrigation, and tillage practices have led to an increase in discharge on the scale of approximately 50 km^3 per year (Raymond et al., 2008). With increased major precipitation events predicted for the future, there is an increased chance of flooding on Refuge divisions making it difficult for management. In addition, river regulation, especially in the Missouri River basin, has changed the timing and volume of flows that reach the middle Mississippi River during various times of the year.

Mississippi River Flows

Average annual discharge, annual peak streamflow, and average monthly discharge trends for the USGS gage at Chester, IL are shown in the figures below (Figure 15, 16, and 17). Missouri River regulation took effect in the early 1950s and it's depicted in Figure 16 that the highest and lowest annual peak streamflows on record occurred before this regulation. After the 1950s the Missouri River most likely did not contribute to many flood peaks other than in 1993. Flood stage is 27 feet (367.73 feet above mean sea level, North American Vertical Datum of 1988) on the gage at Chester, IL. Annual peak streamflow has increased but not significantly since the 1920's. Average annual discharge has significantly increased since the 1940's (p=0.006). Also, average annual discharge has been more variable since about the 1980's compared to earlier records. These increases have been the result of higher-magnitude averages in recent "wet" years. Average monthly discharge trends showed peak discharge occurring between April and May, and tapering off throughout the summer. Over the last few years there have been stage readings at the Chester gage over 30 feet and some even over 40 feet (380.73 feet above mean sea level, North American Vertical Datum of 1988).

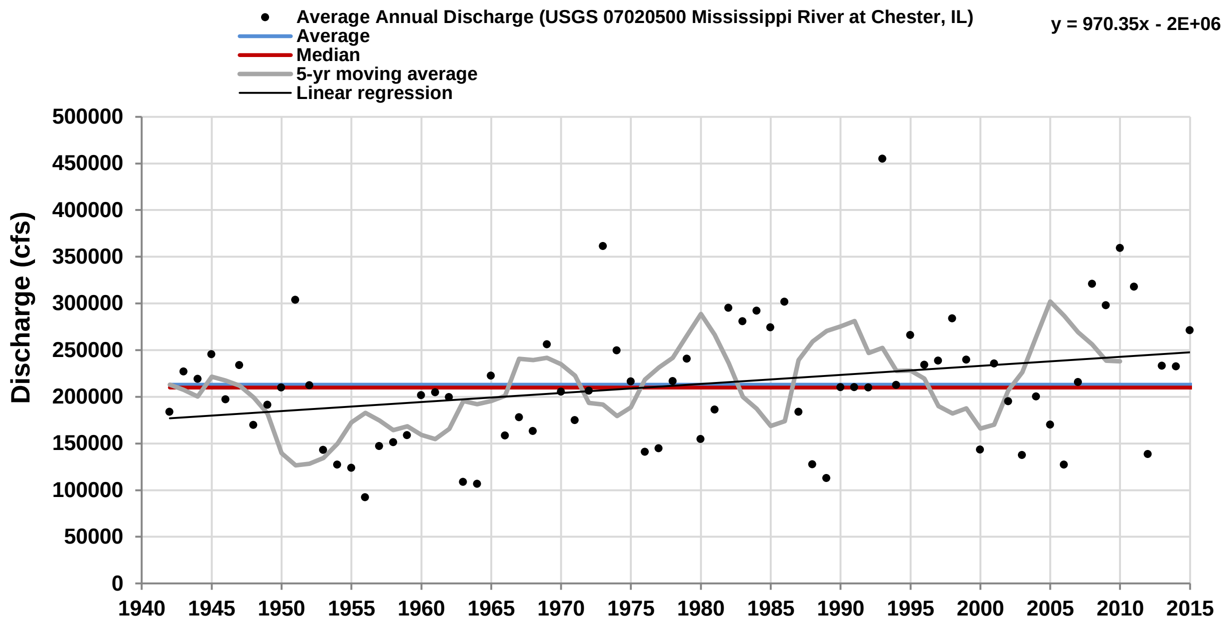

Figure 15: Average annual discharge trends for the Mississippi River at Chester, IL (1942-2016)

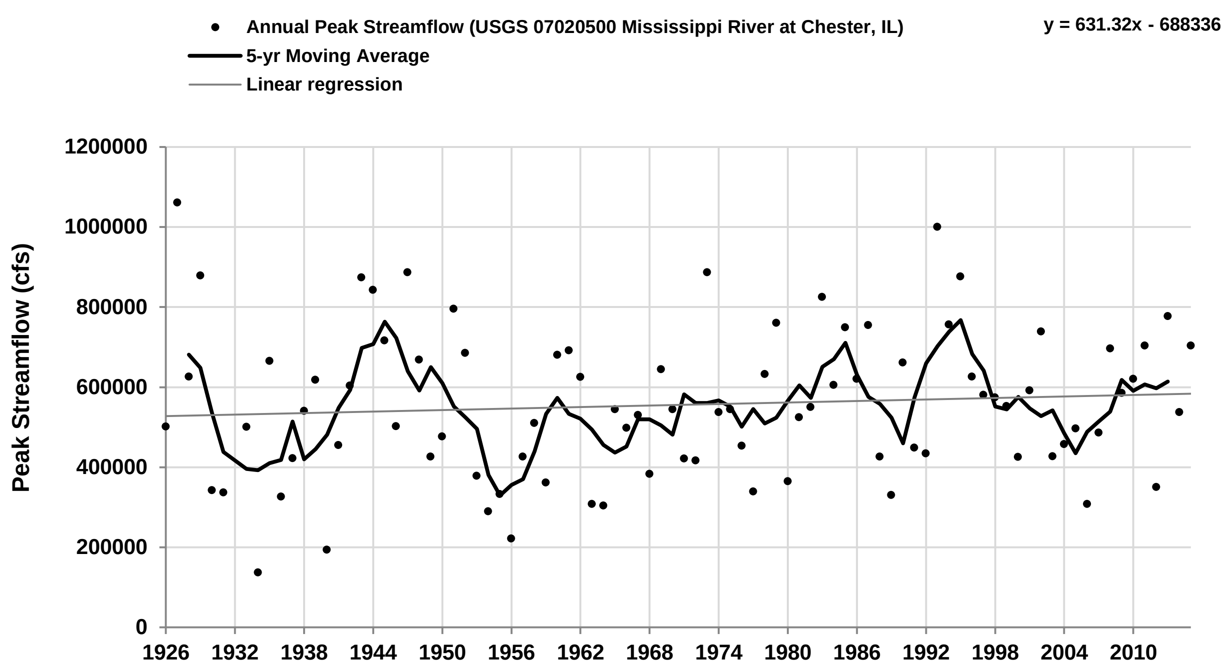

Figure 16: Annual peak streamflow for the Mississippi River at Chester, IL (1926-2015)

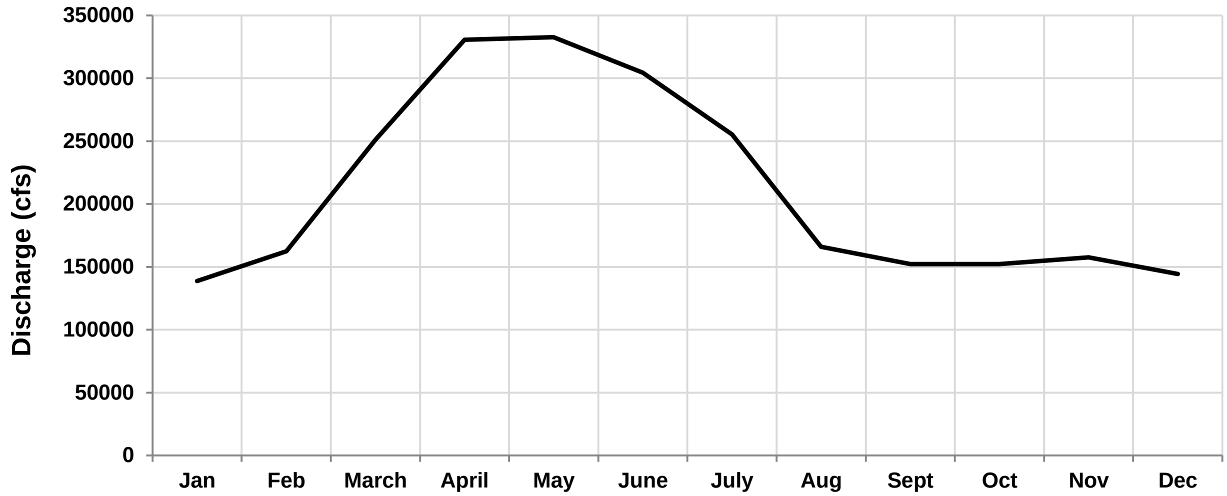

Figure 17: Average monthly discharge data for the Mississippi River at Chester, IL (1942-2016)

Mississippi River Models

The US Army Corps of Engineers developed a tool to model Mississippi River flow frequencies (USACE 2003). Using an unsteady flow hydrologic model in combination with the Bulletin 17B method (IACWD 1982), flood elevations for 2 to 500 year events were derived. The flood frequency is the probability of reaching a particular maximum discharge for a given location on the River in any given year. For example, the 5-year return interval has a 1 out of 5 (20%) probability of occurring in a given year, and a 100-year return interval has a 1% chance of occurring in a given year. These calculated return intervals change due to changing underlying flood pressures. Changing land use and climate are the primary drivers, which invalidate the typical methods of utilizing the entire period of record as a basis of flood elevation calculations (USACE 2003). Table 6 below shows recurrence intervals for each division as depicted in the USACE 2003 report. Stage and peak streamflow recurrence intervals for the last 20 years (1995-2015) were calculated for the gage at Chester, IL using the USGS PeakFQ software (http://water.usgs.gov/software/PeakFQ/) (Table 7). For more information and data pertaining to USACE 2003 flow frequencies for the USGS gage at Chester, IL and other stations along the Mississippi River refer to the following document: Upper Mississippi River System1 Flow Frequency Study-Hydrology and Hydraulics Appendix D, St. Louis District (2003) (http://www.mvr.usace.army.mil/Missions/FloodRiskManagement/UpperMississippiFlowFrequencyStudy.aspx).

Stage levels for recurrence intervals 2-20 years are greater with the PeakFQ assessment (1995-2015) compared to what the USACE 2003 generated (Table 7). As the year of recurrence interval increases (25-years flood frequencies and higher) the stage either does not change between the two assessments or is greater with the USACE 2003 assessment. This is not too surprising considering the greater amount of variability with the increasing amount of years.The Peak FQ assessment did not include large food events like the one in 1993 which would have increased stage values for the recurrence interval years. With this being said, the flood frequencies generated depend on the period of record used. There is a similar trend when looking at streamflow between the USACE 2003 assessment at Chester, IL and the last 20-year analysis using PeakFQ. From recurrence interval years 2-50, streamflow is greater from the last 20 years compared to the longer term assessment done by the USACE in 2003. After the 50-

year recurrence interval streamflows are greater with the long-term assessment done by the USACE. This suggests a greater amount of smaller flood events have occurred recently and maybe the same amount of larger flood events, as compared to looking at greater than 20 years ago. Again, this could very likely be due to using a short period of record for comparison. The differences seen in these two comparison assessments of stage levels and streamflow may not necessarily be representative of a trend. Wet and dry periods could cycle in the future like what has happened in the past. However, it is important to note that stage levels and discharges have increased in recent years, and it will be useful to monitor current flood frequencies down the road to better understand the nature of the Mississippi River. When assessing recurrence intervals there could be trend differences in stage compared to streamflow values. Stage levels can vary depending on changes in the river channel due to scouring and/or sediment deposition.

Peak streamflow and gage height data can be gathered from different sources, primarily from the National Weather Service (NWS) or USGS. When assessing flood frequency recurrence at Chester, IL, differences were observed in peak gage height and river elevation based on what source the data was obtained from (Table 7). The USGS website displays historical data that has gone through QA/QC USGS protocol, so it is corrected for imperfections, whereas the NWS website displays real-time gage height data coming directly from field stations. Data from the NWS website is better used for real-time flood forecasting and data from the USGS website for making accurate water quantity and quality assessments. Additionally, different datums can be referenced, producing slightly different river elevations. The NWS uses the NGVD29 Datum at 341.05 feet and the USGS uses the NAVD88 Datum at 340.73 feet at Chester, IL. In this report all findings related to flood frequency recurrence and associated discussion are based off data obtained from the USGS.

Division	River Mile	Recurrence Interval	Exceedance Probability (%)	Stage (feet, USACE 2003)	Stage (feet, PeakFQ 1995-2015)
Meissner (RM 153.5-155.5)	154	2-years	50	395.4	--------------
		5-years	20	400.8	--------------
		10-years	10	403.8	--------------
		20-years	5	406.5	--------------
		50-years	2	409.8	--------------
		100-years	1	411.7	--------------
		200-years	0.5	412.8	--------------
Harlow (RM 140.5-144)	142.5	2-years	50	389.8	--------------
		5-years	20	395.2	--------------
		10-years	10	398.1	--------------
		20-years	5	400.7	--------------
		50-years	2	403.9	--------------
		100-years	1	405.6	--------------
		200-years	0.5	407.1	--------------
Beaver (RM 116-118)	117.4	2-years	50	376.3	--------------
		5-years	20	381.7	--------------
		10-years	10	384.7	--------------
		20-years	5	387.3	--------------

		50-years	2	390.8	---------------
		100-years	1	392.3	---------------
		200-years	0.5	394.2	---------------
Horse (RM 111-117)	111.6	2-years	50	373.1	---------------
		5-years	20	378.6	---------------
		10-years	10	381.7	---------------
		20-years	5	384.2	---------------
		50-years	2	387.9	---------------
		100-years	1	389.7	---------------
		200-years	0.5	391.9	---------------
Chester, IL USGS Gage	109.9	2-years	50	372.2	375
		5-years	20	377.7	379.8
		10-years	10	380.8	382.3
		20-years	5	383.3	--------------
		25-years	4	-------------	384.9
		50-years	2	387.1	386.5
		100-years	1	389	387.9
		200-years	0.5	391.2	389.1
Crains (RM 104-107)	105.8	2-years	50	369.9	---------------
		5-years	20	375.4	---------------
		10-years	10	378.4	---------------
		20-years	5	380.8	---------------
		50-years	2	384.5	---------------
		100-years	1	386.3	---------------
		200-years	0.5	388.6	---------------
Rockwood (RM 99-104)	101	2-years	50	367.3	---------------
		5-years	20	372.7	---------------
		10-years	10	375.7	---------------
		20-years	5	377.9	---------------
		50-years	2	381.5	---------------
		100-years	1	383.3	---------------
		200-years	0.5	385.7	---------------
Wilkinson (88.5-93)	91	2-years	50	362	---------------
		5-years	20	367.9	---------------
		10-years	10	370.6	---------------
		20-years	5	372.8	---------------
		50-years	2	376.5	---------------
		100-years	1	378.1	---------------
		200-years	0.5	380	---------------

Table 6: Recurrence intervals of the Mississippi River near MMRNWR divisions (USACE 2003)

Date	NWS website peak gage reading at Chester, IL (ft)	River elevation (ft) in reference to NWS website, Zero Gage Datum (NGVD29)	River elevation (ft) in reference to NWS website, NAVD88	USGS website peak gage reading at Chester, IL (ft)	River elevation (ft) in reference to USGS website, Zero Gage Datum (NGVD29)	River elevation (ft) in reference to USGS website, NAVD88
7/1/2008	39.46	380.51	380.19	39.44	380.49	380.17
11/03/2099 (NWS) 5/21/2009 (USGS)	35.61	376.66	376.34	34.86	375.91	375.59
5/21/2010 (NWS) 6/30/2010 (USGS)	36.35	377.4	377.08	36.34	377.39	377.07
5/2/2011	39.74	380.79	380.47	39.74	380.79	380.47
3/26/2012 (USGS)	22.65	363.7	363.38	23.02	364.07	363.75
6/5/2013	42.41	383.46	383.14	42.41	383.46	383.14
7/12/2014	31.8	372.85	372.53	31.80	372.85	372.53
7/2/2015	39.68	380.73	380.41	39.68	380.73	380.41
1/2/2016 (NWS)	45.99	387.04	386.72	--------------	--------------------	---------------------

Table 7: Comparison of river elevations using different datums from NWS (white) and USGS (gray) for the gage at Chester, IL. NGVD29: 341.05 ft and NAVD88: 340.73 ft.
NWS website: http://water.weather.gov/ahps2/hydrograph.php?wfo=lsx&gage=CHSI2
USGS website:
http://nwis.waterdata.usgs.gov/il/nwis/peak?site_no=07020500&agency_cd=USGS&format=html

Flood Frequency Recurrence	≥ 2-Year Flood (50%)	≥ 5-Year Flood (20%)	≥ 10-Year Flood (10%)	≥ 20-Year Flood (5%)
Reference Elevation, ft (based on USACE 2003, NGVD29)	372.2	377.7	380.8	383.3
Years (based on USGS peak gage height)	2008 2009 2010 2011 2013 2014 2015 2016	2008 2011 2013 2015 2016	2013 2016	2013 (using NGVD29) 2016

Table 8: Years of various flood frequency recurrences (2008-2016) based on data from USGS

River Mile	Recurrence Interval	Exceedance Probability (%)	Stage USACE; 1898-1997 (ft)	Stage PeakFQ; 1995-2015 (ft)	Peak Streamflow USACE; 1898-1997 (cfs)	Peak Streamflow PeakFQ; 1995-2015 (cfs)
109.9	2-years	50	372.2	375	480,000	570,300
	5-years	20	377.7	379.8	622,000	699,200
	10-years	10	380.8	382.3	707,000	769,200
	20-years	5	383.3	---------------	--------------	--------------
	25-years	4	---------------	384.9	--------------	845,000
	50-years	2	387.1	386.5	893,000	894,000
	100-years	1	389	387.9	948,000	937,900
	200-years	0.5	391.2	389.1	1,020,000	977,900

Table 9: Comparison of recurrence intervals of the Mississippi River at Chester, IL gage

5.4 Groundwater Levels

Figures 18 and 19 show seasonal groundwater trends throughout the year for two wells located in the Mississippi River floodplain near Festus, MO and Weingarten, MO. The well at Festus, MO may be more relevant because of its close proximity to the Mississippi River floodplain. Festus, MO sits at 425 feet elevation and Weingarten, MO at about 830 feet elevation.

Groundwater trends differ between the two locations. Water levels are higher near Festus, MO compared to levels at Weingarten, MO, approximately 30 miles south. Near Weingarten, MO water levels are lowest late summer, early fall; whereas water levels near Festus, MO are lowest during the winter (December-February). Levels peak in April near Weingarten and in October near Festus. The groundwater trends observed near Weingarten are more what we would expect based on the discharge trends observed in the Mississippi River (higher in spring and lower in late summer). Likely, this well near Weingarten is reflecting seasonal precipitation patterns. It is unusual that there is a long gradual increase in water levels from January to October near Festus, MO and then a sharp decrease from October to December. It appears that this well is likely in use and is regulated. This shows that the aquifer is sensitive to pumping. The differences seen between the two stations could be due to the fact that each station is located within a different aquifer and/or the difference in elevation between the two sites. Festus, MO is located within the Salem Plateau Groundwater Province, consisting of the St. Francois and Ozark aquifers. These are primarily comprised of sandstone, limestone, and dolomite (http://dnr.mo.gov/geology/wrc/groundwater/education/provinces/salemplatprovince.htm). Weingarten, MO is located within the Springfield Plateau Groundwater Province. This borders the Salem Plateau Groundwater Province so there is overlap in the aquifers present (St. Francois and Ozark). The geology of the Springfield Plateau also consists of sedimentary, igneous and metamorphic rock; however, the position and thickness of rock varies throughout the Province compared to the Salem Plateau (http://dnr.mo.gov/geology/wrc/groundwater/education/provinces/springfieldplatprovince.htm).

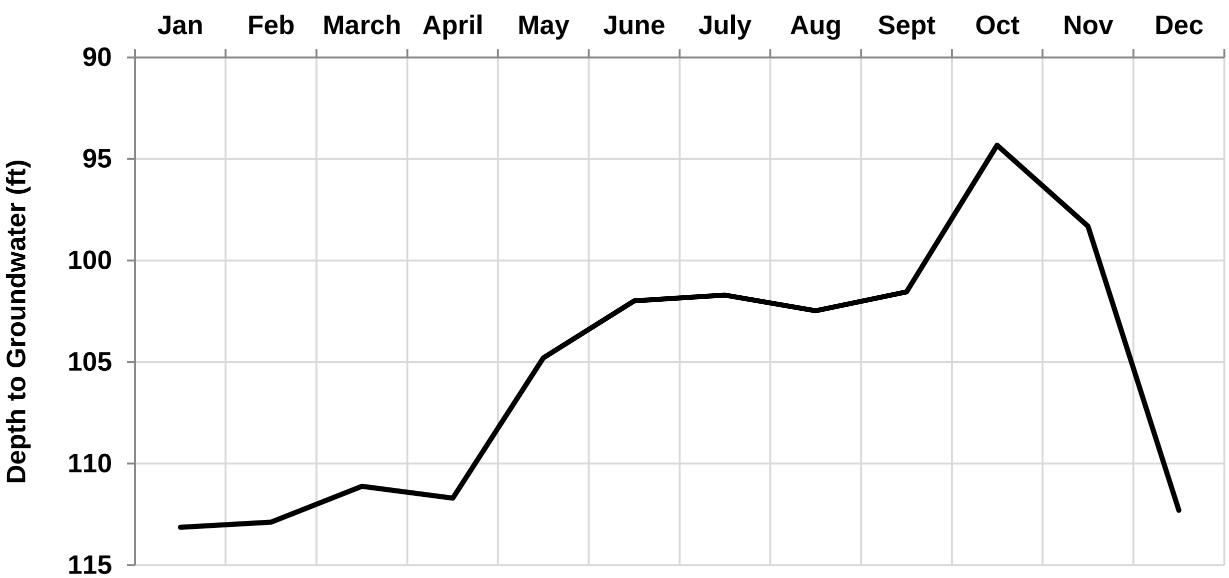

Figure 18: Average monthly depths to groundwater at Festus, MO (2002-2016)

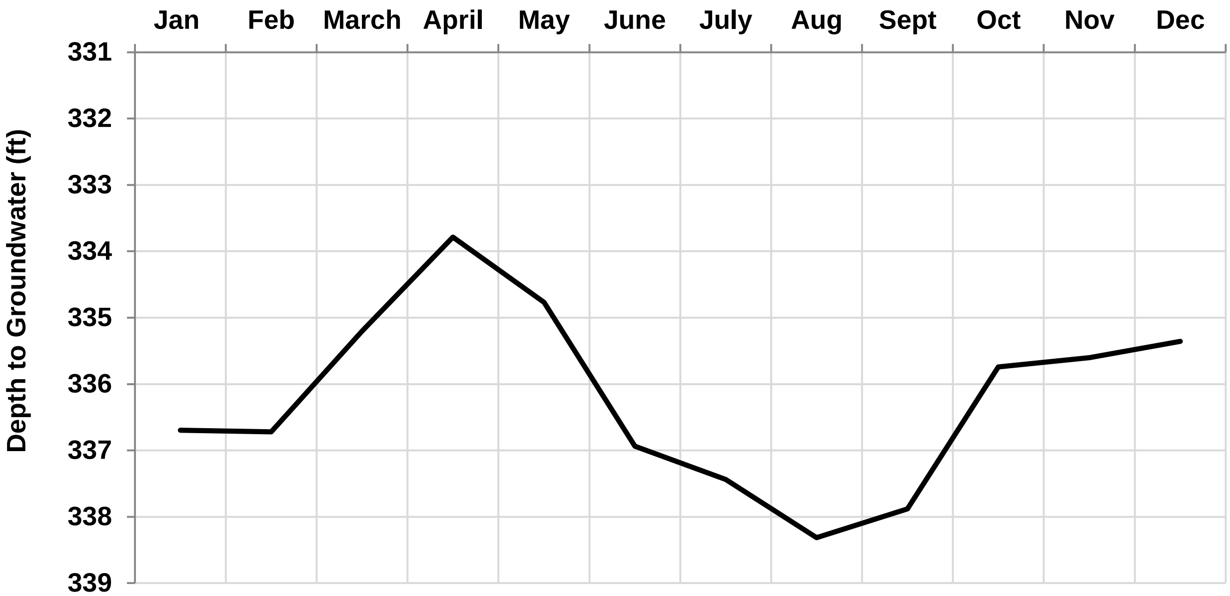

Figure 19: Average monthly depth to groundwater at Weingarten, MO (2009-2016)

5.5 Water Quality

303(d) Assessments

Section 303(d) of the Clean Water Act requires that each state identify water bodies where water quality standards are not met based on designated usage. Section 303(d) data from the State of Missouri (2014) and the State of Illinois (2016) were utilized to identify any impaired streams, rivers, creeks, or lakes on or in close proximity to MMRNWR. There were no relevant 303d listed impaired lakes. The relevant 303d listed impaired lotic water bodies included the Mississippi River, the Meramec River and its tributaries, the Kaskaskia River and its tributaries, and the Cinque Hommes Creek. The following table (Table 8) lists these water bodies and the designated use(s) that is impaired along with the cause(s) of that impairment.

Water body	Designated Use(s) Impaired	Cause(s) of Impairment
Mississippi River	Primary contact recreation	Fecal coliform
	Fish consumption	Mercury
Meramec River and tributaries	Aquatic life protection	Lead (old lead belt tailings), chloride (urban runoff/storm sewers), mercury deposition
	Primary contact recreation	*Escherichia coli* (urban runoff/storm sewers, rural nonpoint source)
Kaskaskia River and tributaries	Fish consumption	Mercury
	Public and food processing water supplies	Iron
	Aquatic life protection	Iron, sedimentation/siltation, total phosphorus, dissolved oxygen, manganese

Cinque Hommes Creek	Primary contact recreation	*Escherichia coli* (rural nonpoint source)

Table 10: 303d listed impaired streams relevant to MMRNWR

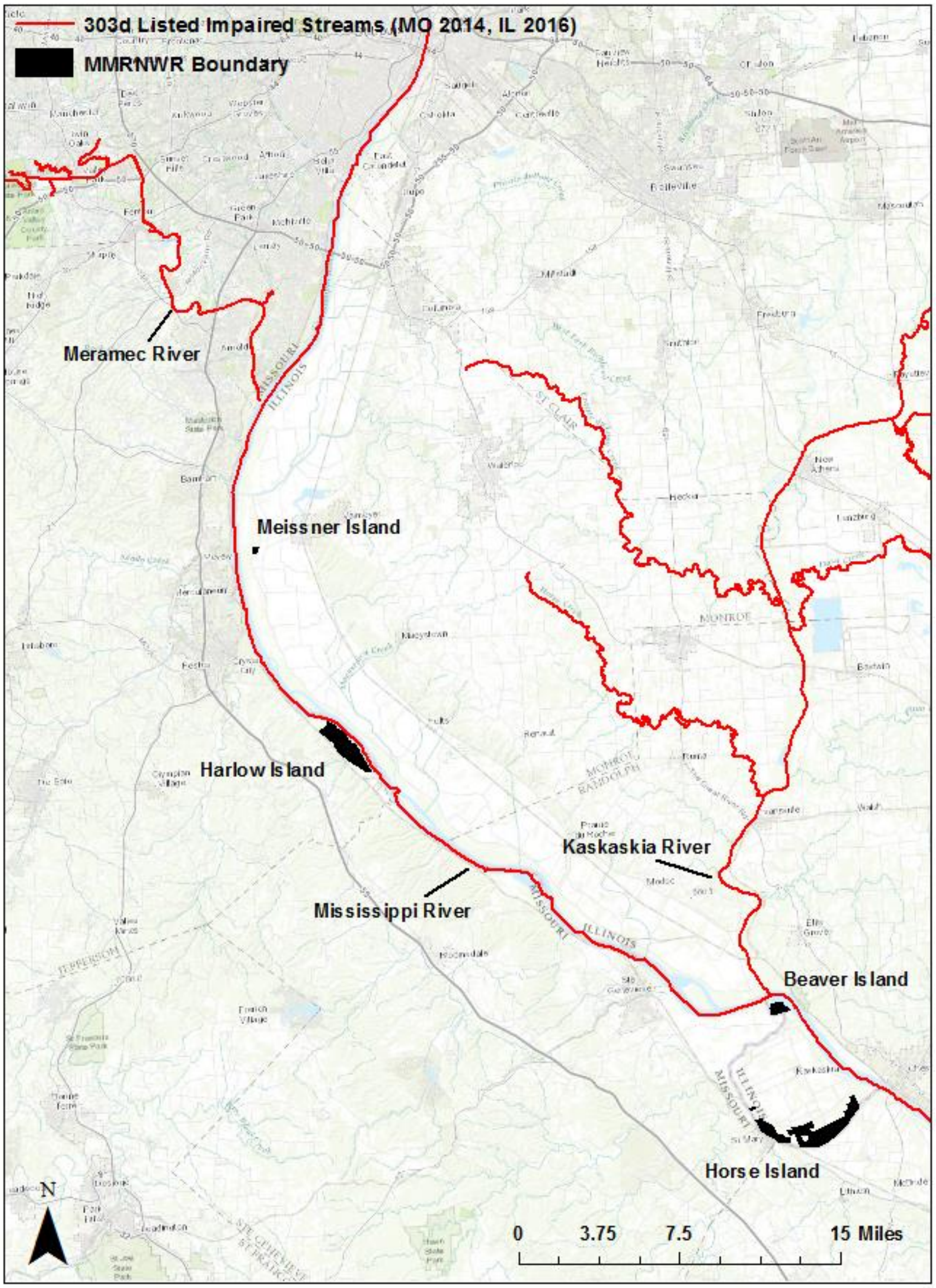

Figure 20: Map of impaired streams near MMRNWR

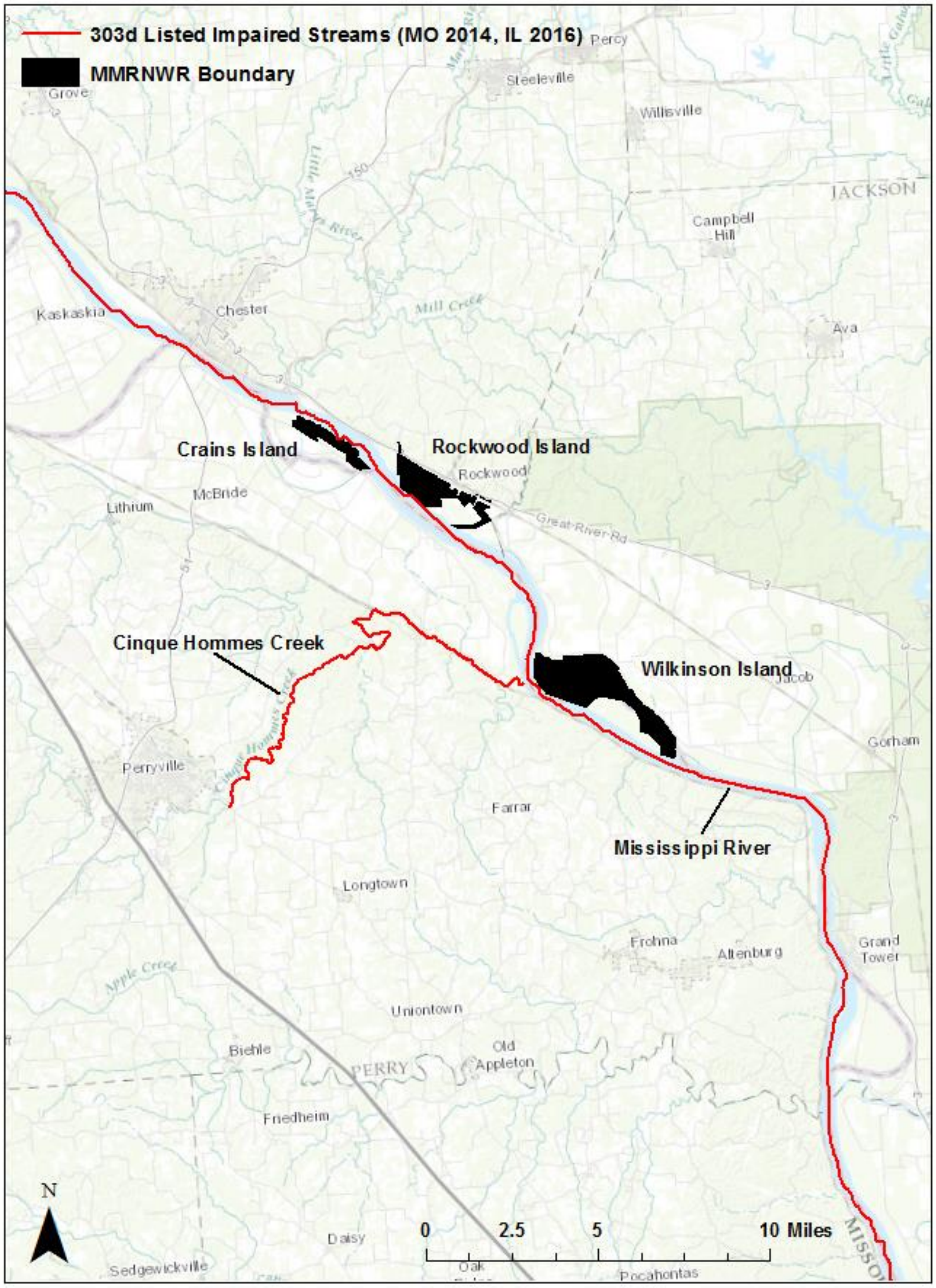

Figure 21: Map of impaired streams near MMRNWR continued

Mississippi River Water Quality

Because of the immense size of the Mississippi River watershed, water quality in the Mississippi River is primarily influenced by extensive, wide-scale sources such as regional agricultural practices and impacts from heavily developed areas. Nutrients, pollutants, and sedimentation are the major water quality issues in the middle Mississippi River. Agricultural development, land use change, levee construction, and channelization have caused an increase in suspended sediments and sedimentation rates in the watershed over time (Theiling et al. 2000). The Upper Mississippi River has experienced an overall increase in sediment loads, while the Missouri River has experienced a decrease in sediment loads. However, the Missouri River still contributes 75-95% of the sediment loads seen in this reach of the Mississippi River (Davinroy 2006). There have been significant increases in nutrient concentrations and loadings of phosphorus and nitrate, along with decreases in silicate in the Mississippi River this century, and this has accelerated since 1950 (Rabalais et al. 1996). High turbidity and reduced water clarity result in decreased aquatic vegetation throughout the floodplain wetlands. In addition, increased nutrient levels throughout the Mississippi River have resulted in the "dead zone" in the Gulf of Mexico, a large area of anoxic conditions (Mississippi River Water Quality and the Clean Water Act: Progress, Challenges, and Opportunities http://www.nap.edu/catalog/12051.html). Middle Mississippi River National Wildlife Refuge is one of the limited protected areas along the Mississippi River. It is important to protect, maintain, and work to create more desirable wetland habitat at the Refuge, therefore helping to alleviate some potential serious nutrient problems downstream. Locally, floodplain restoration and connectivity could help to improve water quality by allowing for nutrient cycling, filtering out pollutants, and increasing sediment capture. However, to improve water quality for the whole Mississippi River there needs to be improved land and water management throughout the watershed.

Within the Mississippi River there exists legacy contamination from metals and organic compounds, including lead, PCB's, and PAH's (Mississippi River Water Quality and the Clean Water Act: Progress, Challenges, and Opportunities http://www.nap.edu/catalog/12051.html). However, of greater concern may be the increased introduction of emerging contaminants, such as pesticides and pharmaceuticals. Legacy contaminants have been studied more extensively than emerging contaminants and are already existent within the environment. Emerging contaminants primarily pose chronic impacts to an ecosystem and are more difficult to study because there is continuous input of these from nonpoint sources, and in the presence of other chemicals they can cause unpredictable mixture effects. The potential for runoff from primarily agricultural land and some smaller urban areas is great around MMRNWR. Also, with the abundance of tributaries feeding the Mississippi River, the presence of emerging contaminants is likely high, especially during flood events. Refuge divisions that may be particularly vulnerable to agricultural runoff include Horse, Crains and Wilkinson Islands (John Hartleb and Jason Wilson, personal communication). A wide variety of contaminants are hydrophobic and therefore adhere or are absorbed into sediments. Thus, areas in the River where sediment is deposited can become "hot spots" for a mix of toxic substances (Mississippi River Water Quality and the Clean Water Act: Progress, Challenges, and Opportunities http://www.nap.edu/catalog/12051.html).

High fecal bacteria counts were once a greater concern in the Mississippi River when there was no ban on raw sewage discharge. This water quality issue has been greatly reduced with the implementation of secondary sewage treatment plants, however excess fecal bacteria counts can still exist, primarily around larger urban areas (Mississippi River Water Quality and the Clean Water Act: Progress, Challenges, and Opportunities http://www.nap.edu/catalog/12051.html). There are no large municipalities (>15,000 population) within the MMRNWR stretch, but its location not far downstream of St. Louis, MO puts the Refuge at risk of increased fecal bacteria counts at times.

Water chemistry data for the Mississippi River within the MMRNWR reach was obtained from the Illinois DNR, however there were insufficient data for key water quality parameters and recent years so it was not included in this report.

Groundwater Quality

It has been noted that areas of high salinity exist near the Rockwood Island division (discussions with Refuge staff). However, the occurrence is spotty; one can go 100 yards away drill a well and salinity is not an issue. No information was found in a literature search regarding this situation. However, there are a handful of possible causes of increased salinity in this area, including dissolution of soil, rock, and organic material; application of synthetic fertilizers and manure on cropland; and nearby wastewater treatment facilities. There are no wells in use on the Refuge.

Chapter 6: Water Law

Middle Mississippi River NWR does not engage in any active water management activities, such as water withdrawals or diversions, that would have associated permitting requirements under state laws. Below, the water laws for Missouri and Illinois are provided as a reference for any potential water management considerations in the future and as information that could be used to protect refuge water supplies from being abused by other users.

Given that the Refuge divisions are in both Missouri and Illinois, subtle differences in applicable water law do exist, despite a common basis in riparian right doctrine. In states that apply the riparian rights doctrine, landowners of property with naturally flowing surface water running through or adjacent to their property have rights to reasonable use of the surface water associated with the property itself. The “reasonable use” standard protects downstream users by ensuring that one landowner’s use does not unreasonably impair the equal riparian rights of others along the same watercourse. Additionally, the law limits riparian rights to those rights “intimately associated” with the water; uses falling outside of this definition are usually considered unreasonable uses.[1]

An important corollary to the riparian rights doctrine is that, generally, states classify their navigable[2] surface waters as public, whether through statute or through the common law public trust doctrine.[3] This is important because on public waters, the riparian landowners’ rights are subject to public rights of, at a minimum, navigation. For this reason, states regulate waters for the purpose of putting the water to “beneficial use,” a term defined differently amongst the states.

Missouri

Missouri’s judicially defined reasonable-use rule provides that riparian owners have the “right to the flow of the stream in its natural course and natural condition in respect to both volume and purity, except as affected by reasonable use by other proprietors.”[4] Landowners’ riparian rights include “the limited right to use the water to irrigate [their] land,” so long as the “natural wants” of other riparian owners are met.[5] These “natural wants,” consisting of “drinking water for family and livestock,” take priority over other water uses.[6] Courts determine what constitutes reasonable use on a case-by-case basis, looking at, among other things, “the volume of water in the stream, the seasons and climatic conditions, and the needs of other riparian proprietors.”[7]

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[1] John W. Johnson, United States Water Law: An Introduction 38 (CRC Press, 2009).
[2] “Navigable,” in this context, is a legal term of art that varies from state to state, separating public waters from those that are private. As a general notion, “navigable” means navigable in fact, which, historically, has been tested by whether or not a log or canoe could float on the water. *See, e.g.*, Paul G. Kent & Tamara A. Dudiak, *Wisconsin Water Law: A Guide to Water Rights and Regulations* 4 (University of Wisconsin-Extension, 2d ed., 2001).
[3] The public trust doctrine, in most states, refers to the concept that state, as trustee to the public, preserves navigable waters “for public use in navigation, fishing and recreation.” Black’s Law Dictionary 1232 (6th ed. 1990). This prohibits the state from selling the beds to private parties.
[4] *Bollinger v. Henry*, 375 S.W.2d 161, 166 (Mo. 1964).
[5] Id.
[6] Id.
[7] Id.

The state of Missouri does not have a sophisticated water permitting system like some of the other Region 3 states. However, it has taken some measures to, at a minimum, inventory and plan for long-term water resource use. The state tasked the Missouri Department of Natural Resources (DNR) to develop a State Water Resources Plan in order to assess the existing and future needs of surface and ground water for “drinking water supplies, agriculture, industry, recreation, environmental protection and related needs.”[8] As part of the state water resources program, the DNR also has the duty of creating a plan for water resource emergencies.[9] The water inventory examines: (1) existing surface and groundwater uses, (2) quantities available for future uses, and (3) water extraction and use patterns, including both regulated and unregulated users.[10] Based on the collected data, DNR can then make recommendations annually to the general assembly about potential statutory revisions that should be made related to the state’s water laws.[11]

DNR uses a registration program to facilitate its water resource inventory. The program requires “major water users,” or those users with a “water source and equipment necessary” to withdraw or divert at least 100,000 gallons-per-day from any surface or ground water source,[12] to register with the Missouri Division of Geology and Land Survey by providing information regarding the water source, the installation, the purpose used, the time of year withdrawals will be made, and the daily and annual amounts withdrawn.[13]
Missouri has implemented a smattering of either permit programs or regulations for other activities on public waters. As an example, the state requires permits for dam construction on public waters,[14] which includes a requirement to construct a chute for fish.[15] Failure to construct a chute to the statutorily defined parameters constitutes a public nuisance.[16] Also, the state, through its Well Installation Board, regulates well drilling to a limited extent.[17]

At the local level, the state has authorized communities to establish water supply districts, water conservancy districts, drainage districts, and levee districts. Community public water supply districts may determine the scope of the district and have powers delegated by the state, such as eminent domain and taxation, to administer the construction and maintenance of a water supply.[18] Similarly, community members can establish water conservancy districts that focus on protection of a primary water source in their region.[19] These districts have the delegated power to take actions such as imposing fees on irrigation wells.[20] Since excessive water seems to pose more of a threat to Missouri citizens than water shortages, community-administered drainage and levee districts exist to construct projects for the purpose of reclaiming swampland for either sanitary or agricultural reasons, so long as the drainage or levee activities do not negatively impact the public.[21] The state places much emphasis on the role of local communities to control water resources.

[8] Missouri Rev. Stat. § 640.415.
[9] Missouri Rev. Stat. §256.440–443.
[10] Missouri Rev. Stat. § 640.412
[11] Missouri Rev. Stat. § 640.415.
[12] Missouri Rev. Stat. § 256.400(4).
[13] Missouri Rev. Stat. § 256.410.
[14] Missouri Rev. Stat. § 236.435.
[15] Missouri Rev. Stat. § 236.230.
[16] Id.
[17] Missouri Rev. Stat. §§ 256.600-256.660.
[18] Missouri Rev. Stat. §§ 247.010–247.673.
[19] Missouri Rev. Stat. §§ 256.030–256.070.
[20] Missouri Rev. Stat. § 256.655.
[21] Missouri Rev. Stat. § 242.563; *see, also*, Missouri Rev. Stat. §§ 242.010–242.750, 245.010–244.205.

Illinois

Illinois does not have a sophisticated means for claiming rights to water, especially for instream water rights. As a state that generally follows the traditional riparian rights doctrine,[22] all landowners adjacent to a body of water have a right to reasonable use of the water, so long as it does not impact the same rights as other similarly situated landowners.[23] The legislature codified surface and ground water into one system under the Water Use Act of 1983, which extended the common law reasonable-use rule to groundwater withdrawals.[24]

The statute specifically defined "reasonable use," in keeping with the common law, as "the use of water to meet natural wants and a fair share for artificial wants. It does not include water used wastefully or maliciously."[25] In Illinois, "natural wants" refer to uses necessary to the land, mainly domestic uses.[26] "Artificial wants," on the other hand, refer to uses that would increase "comfort and prosperity."[27] In times of shortage, the state will prioritize natural wants over artificial wants, and once natural wants are satisfied, water users may consume their "just proportion" of artificial wants.[28] Courts ultimately determine on a case-by-case basis whether a water user has consumed beyond his "just proportion," looking at the relative needs of the water users and the water availability.[29]

With the reasonable-use rule as a foundation, Illinois allows communities to regulate groundwater consumption through the establishment of water authorities, in order to give communities the power to take control of their local resource. The Water Authority Act (WAA) sets out a detailed and extensive procedure for citizens to create a water authority, but once established, the local authority has broad powers.[30]

At least thirteen water authorities have been established since the law was enacted, mostly in the eastern-central part of the state.[31] However, the WAA specifically excludes water used for agricultural purposes, irrigation, and small domestic wells for less than four families from the Authorities jurisdiction.[32] The law does not provide any specific authority for water authorities to ensure minimum flows or instream uses, but at least provides a broad catchall, allowing authorities to "make such regulations as it deems necessary to protect public health, welfare and safety and to prevent pollution of its water supply."[33] This may be the only provision FWS could rely upon to protect instream flows within a local water authority region.

In addition to the local water authorities, the Illinois Department of Natural Resources (DNR) has jurisdiction over public waters, and the agency has a duty to document all navigable waters and

[22] *Evans* v. *Merriweather*, 4 Ill. 491 (1842); *Knaus v. Dennler*, 525 N.E.2d 207, 209 (Ill. App. Ct. 1988).
[23] Gary R. Clark, *Illinois Groundwater Law: The Rule of Reasonable Use* 14–15 (State of Illinois, Department of Transportation and Division of Water Resources 1985).
[24] Water Use Act of 1983, 525 Ill. Comp. Stat. 45/6 (2011).
[25] 525 Ill. Comp. Stat. 45/4.
[26] *Evans* v. *Merriweather*, 4 Ill. 491, 495 (1842).
[27] Id.
[28] *Bliss v. Kennedy*, 43 Ill. 67, 74 (1867).
[29] *Id.* at 76–77.
[30] 70 Ill. Comp. Stat. 3715/1 *et seq.* (2011).
[31] *See* http://www.isws.illinois.edu/docs/wsfaq/wsmore.asp?id=q6; http://www.agr.state.il.us/marketing/IALD/organizations/IALDDirectory%2058.pdf.
[32] 70 Ill. Comp. Stat. 3715/8 (2011).
[33] 70 Ill. Comp. Stat. 3715/24 (2011).

"jealously guard the true and natural conditions" of state waters.[34] Under this policy, DNR's Office of Water Resources manages a permit system for construction projects in public water ways, i.e. navigable waters, and for public water developments that may impact public rights to use the water.[35]

In Illinois, FWS has a right to the reasonable use of surface and ground water associated with the boundaries of the refuges. While FWS cannot affirmatively assert its right to instream use, it may have a claim against other water users if a shortage occurs, even if that right consists of a just proportion of its natural wants.[36] However, these issues have yet to be explored by the courts.

[34] 615 Ill. Comp. Stat. 5/5 (2011).
[35] Ill. Admin. Code tit. 17 §§ 3700, 3704, 3708 (2010).
[36] Illinois courts have not spoken on whether instream uses for fish and wildlife purposes would constitute a natural want.

Chapter 7: Geospatial Data Sources

Land cover data was obtained from the NRCS Geospatial Data Gateway-National Land Cover Dataset by State (NLCD) (2011). https://gdg.sc.egov.usda.gov/

HUC polygons are available from the EPA as part of the Watershed Boundary Dataset (https://www.nrcs.usda.gov/wps/portal/nrcs/main/national/ngce/). These boundaries were delineated in cooperation with the USGS using methodology adapted from Seaber et al. (1987).

The most recent high resolution LiDAR data (1 m cell size) is available in the North American Vertical Datum (NAVD 1988). This data was processed by Vince Capeder (USFWS 2016).

The National Wetland Inventory-USFWS. 1985-1986. National Wetlands Inventory website. U.S. Department of the Interior, USFWS, Washington, D.C. http://www.fws.gov/wetlands/

The National Hydrologic Dataset (NHD) is produced as a cooperative effort by the Environmental Protection Agency (EPA), the U.S. Geological Survey (USGS), and other federal and state agencies.

Soil Survey Staff, Natural Resources Conservation Service, United States Department of Agriculture. Soil Survey Geographic (SSURGO) Database for Illinois and Missouri.

303(d) impaired waters were obtained from the Missouri Spatial Data Information Service (MSDIS) http://www.msdis.missouri.edu/data/ and from the State of Illinois EPA (data files from David Muir)

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PALLID STURGEON: http://www.fws.gov/midwest/endangered/section7/pallid.html

http://www.ucsusa.org/sites/default/files/legacy/assets/documents/global_warming/climate-change-illinois.pdf (UCS 2009)

http://www.ucsusa.org/sites/default/files/legacy/assests/documents/global_warming/climate-change-missouri.pdf (UCS 2009)

Appendix A: Elevation Data

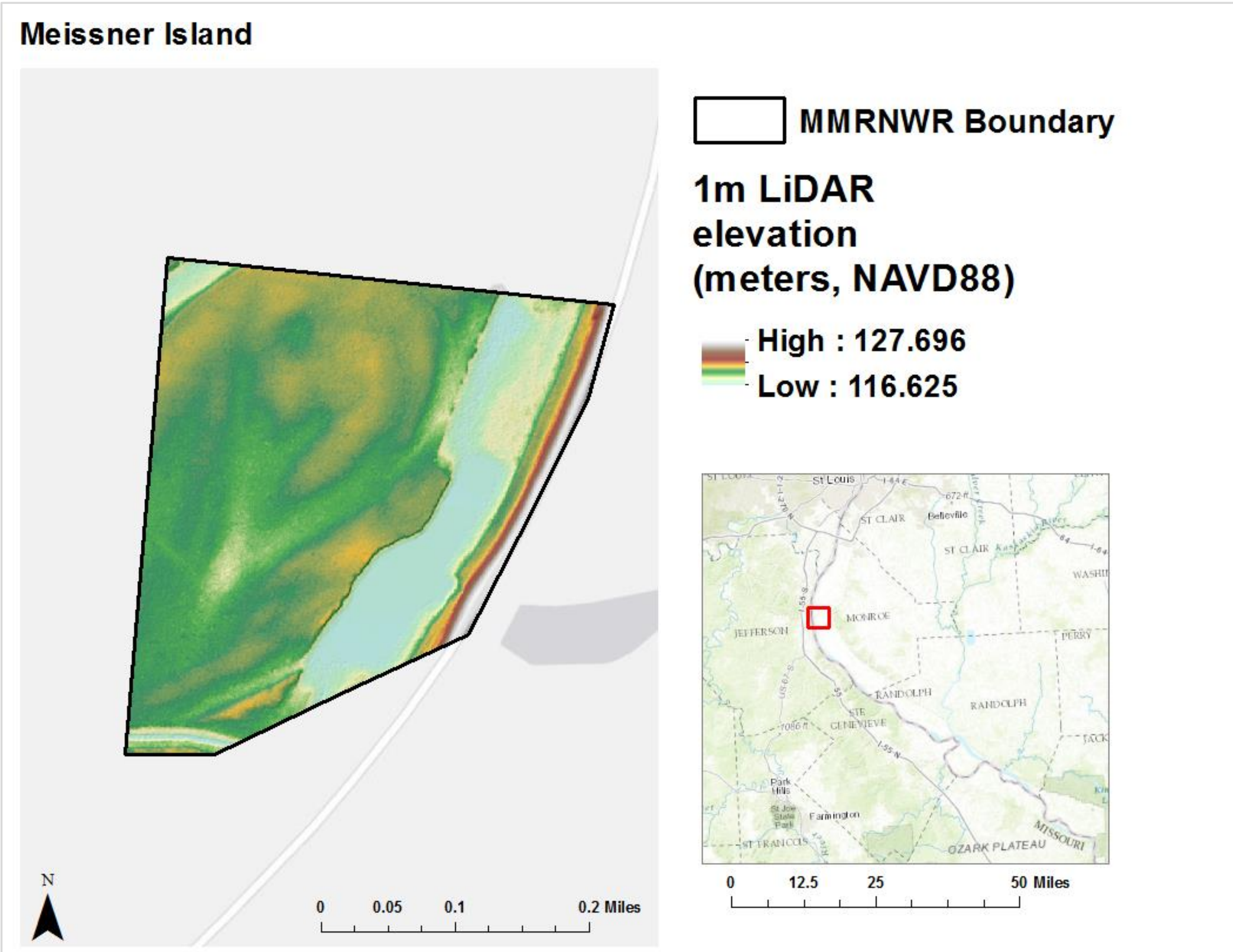

Figure 22: LiDAR data for Meissner Island

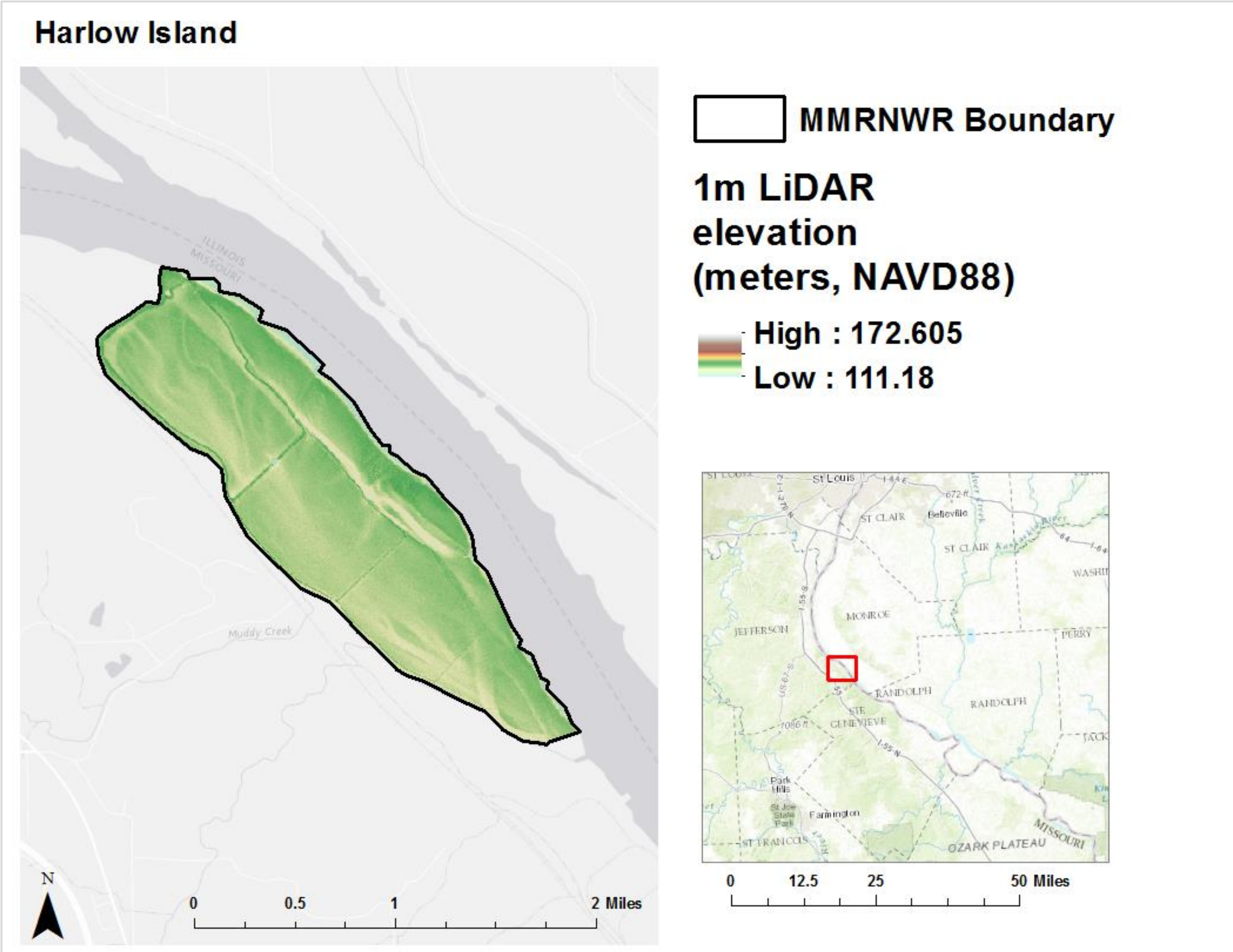

Figure 23: LiDAR data for Harlow Island

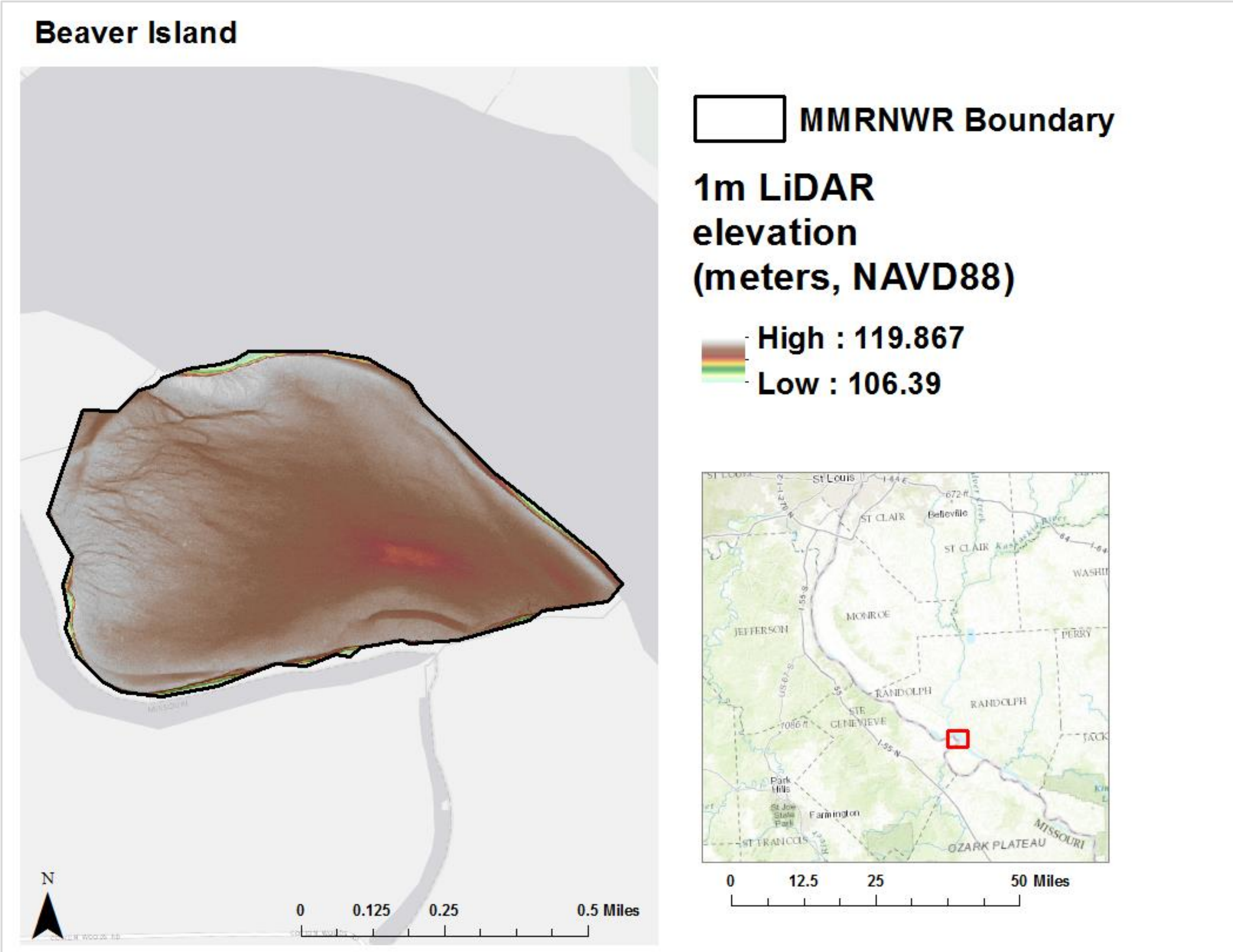

Figure 24: LiDAR data for Beaver Island

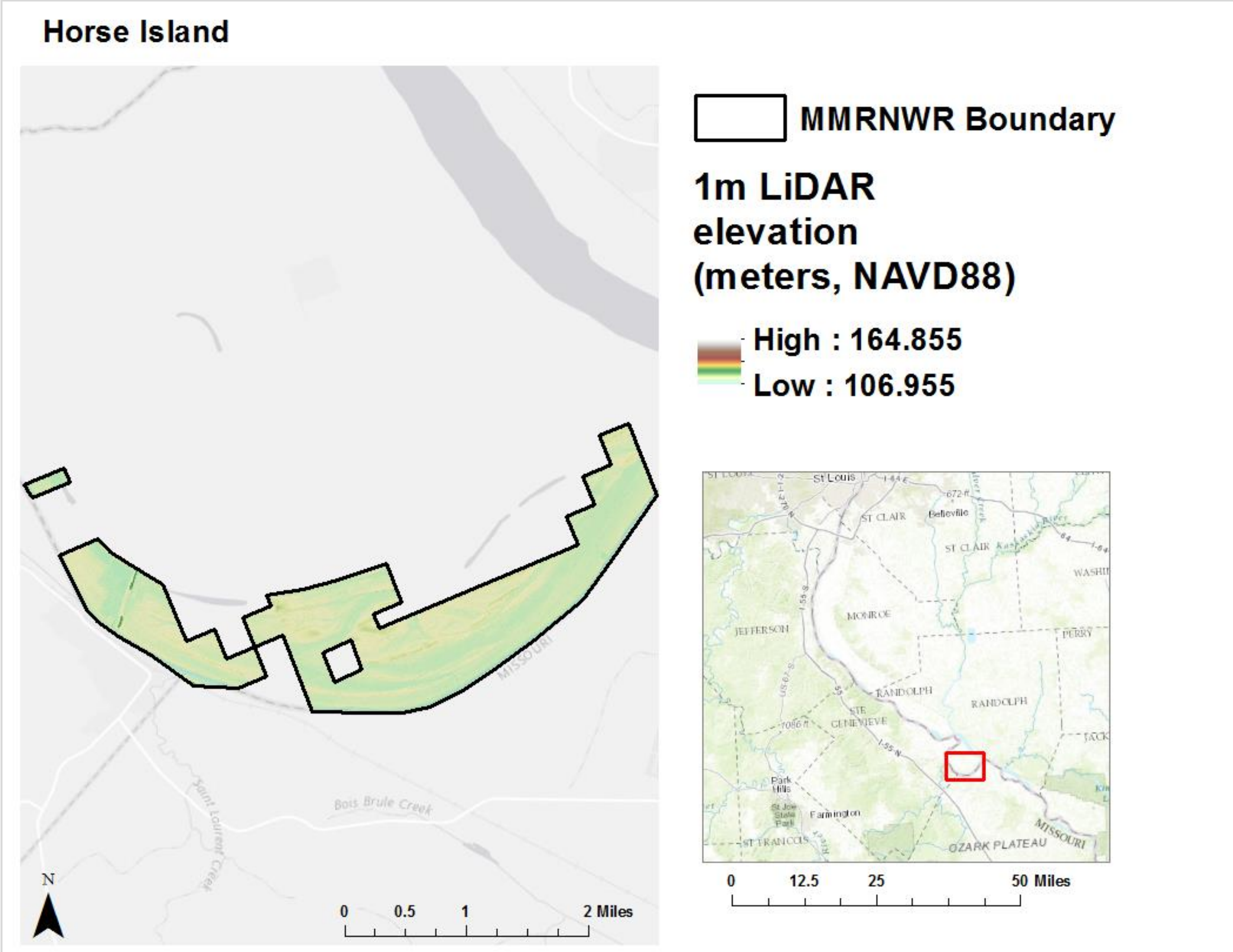

Figure 25: LiDAR data for Horse Island

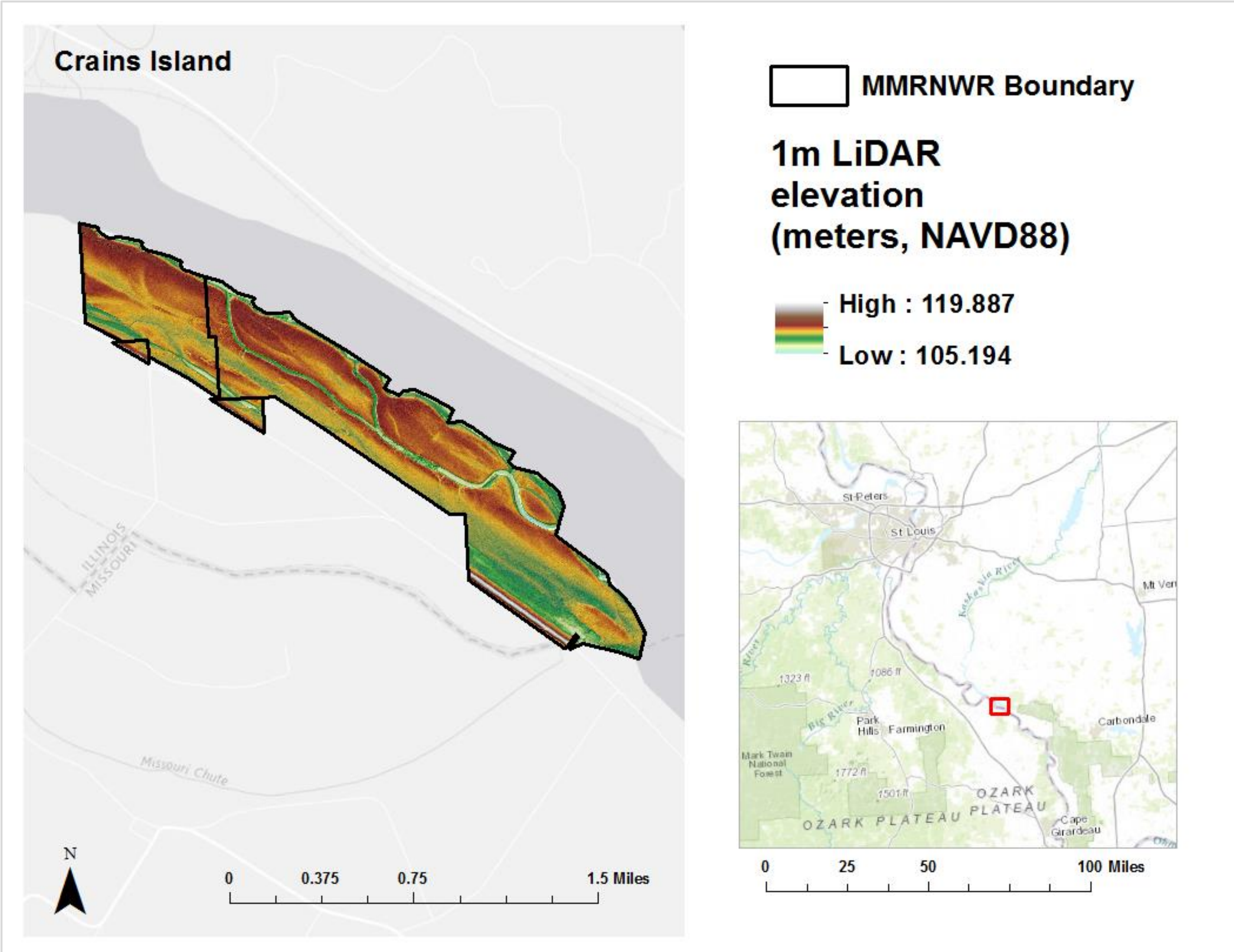

Figure 26: LiDAR data for Crains Island

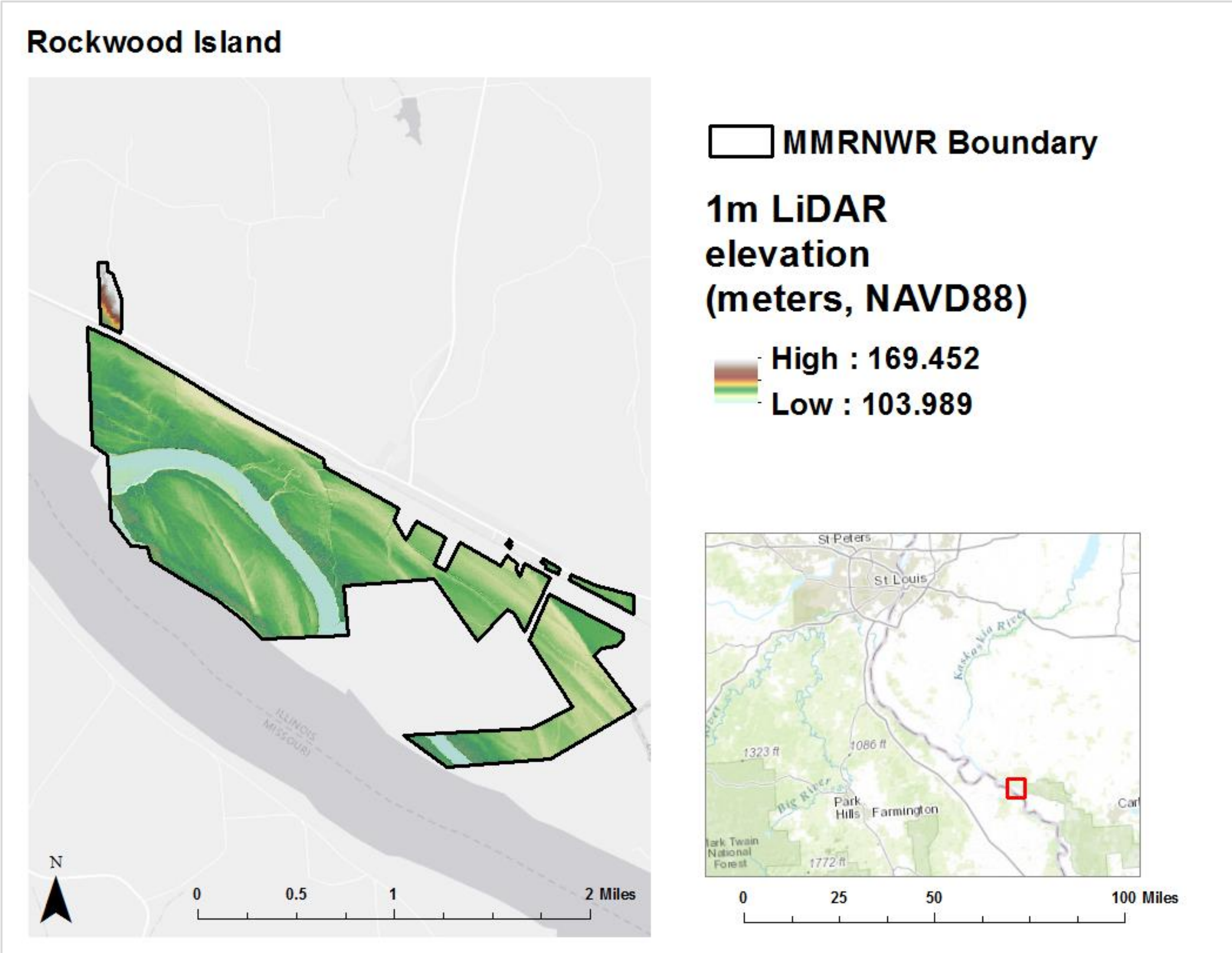

Figure 27: LiDAR data for Rockwood Island

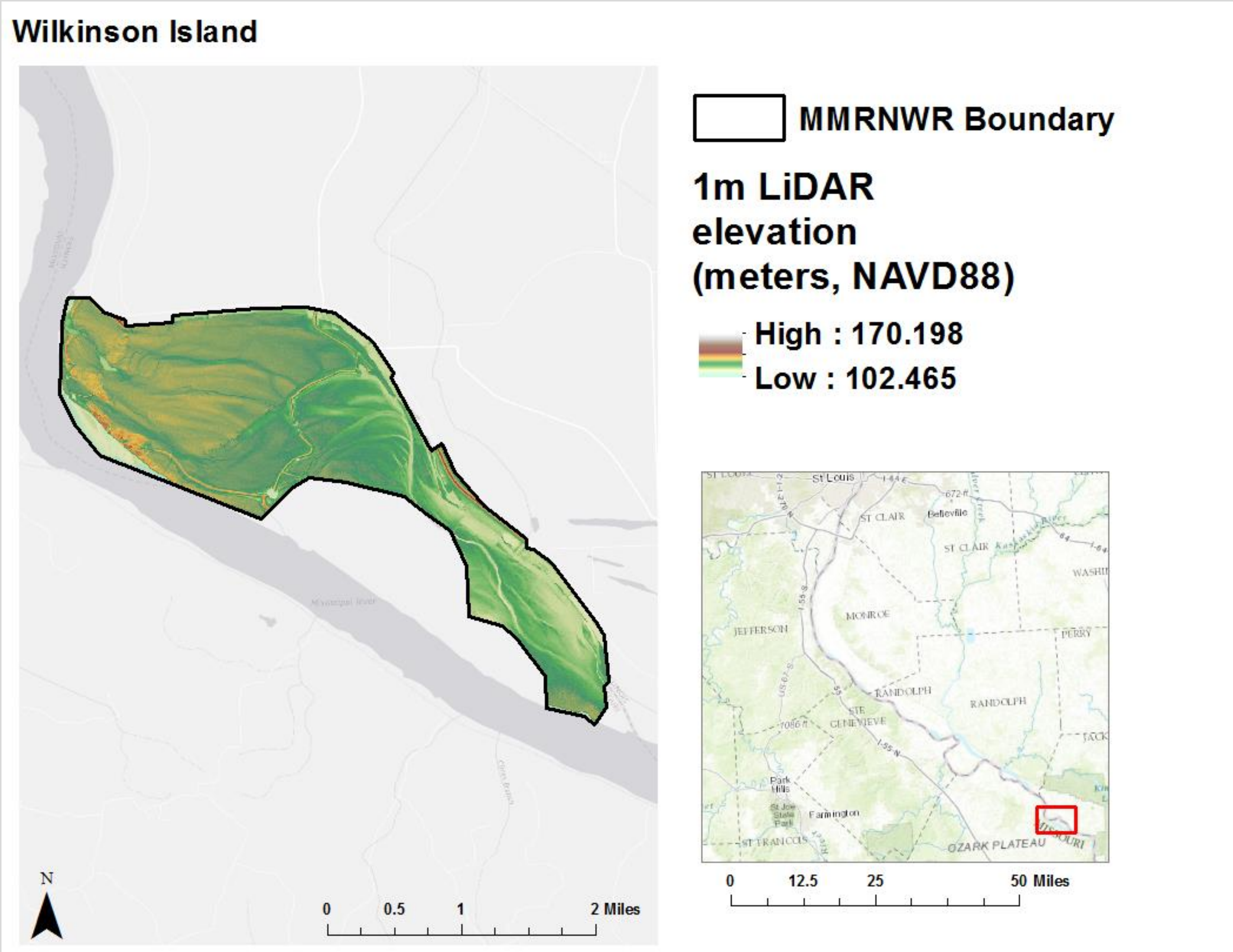

Figure 28: LiDAR data for Wilkinson Island

Appendix B: SSURGO Soils Data

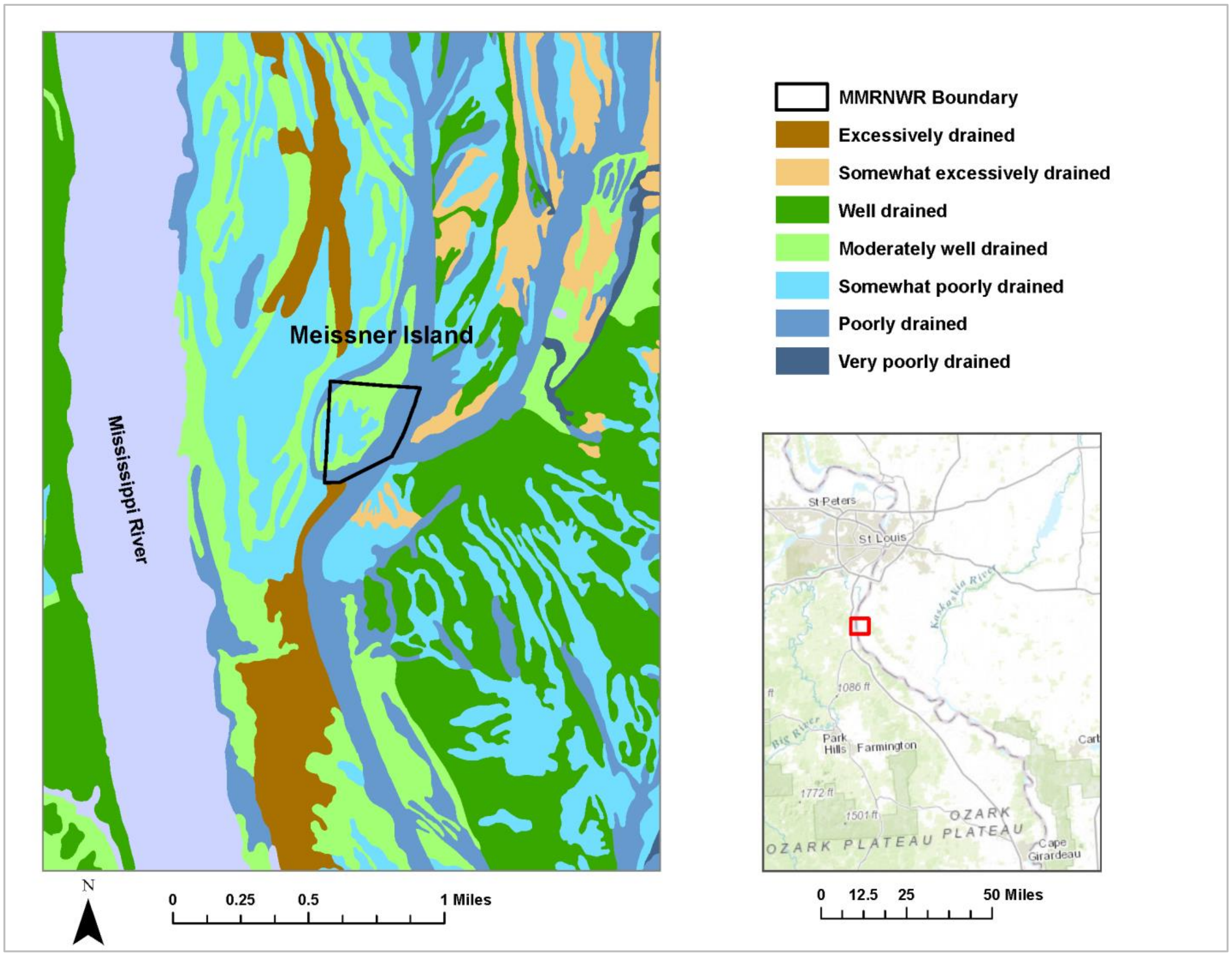

Figure 29: Soil drainage map for Meissner Island

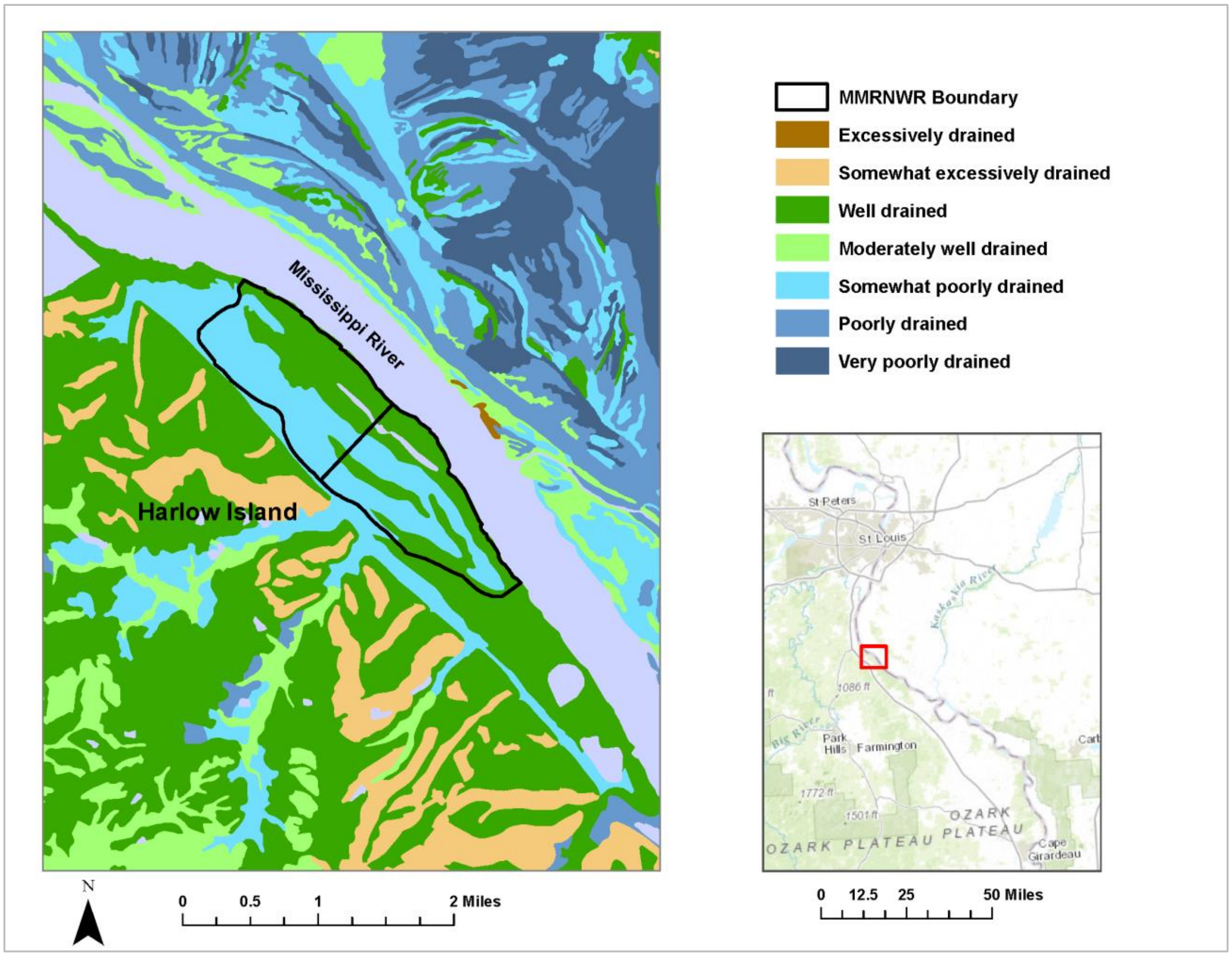

Figure 30: Soil drainage map for Harlow Island

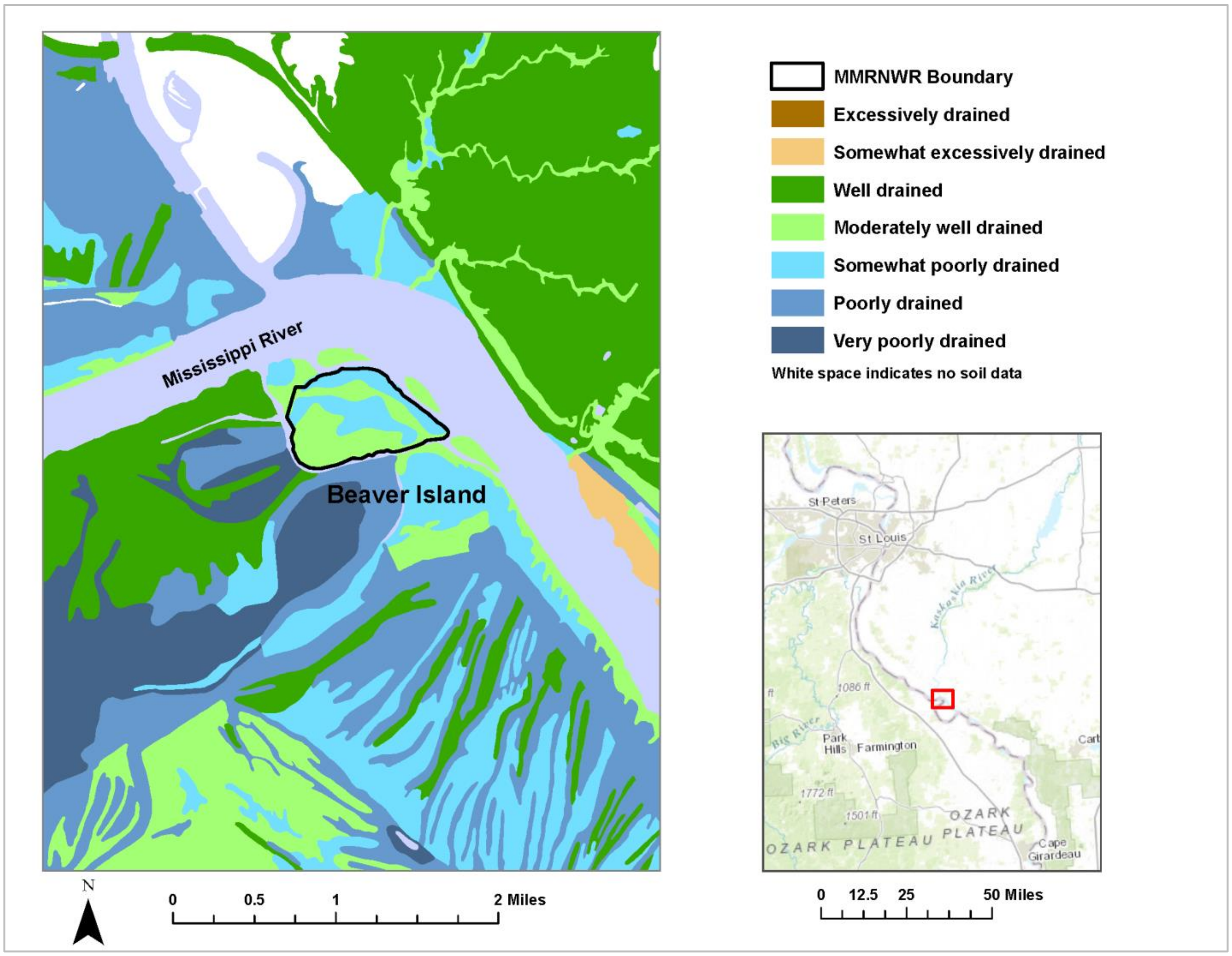

Figure 31: Soil drainage map for Beaver Island

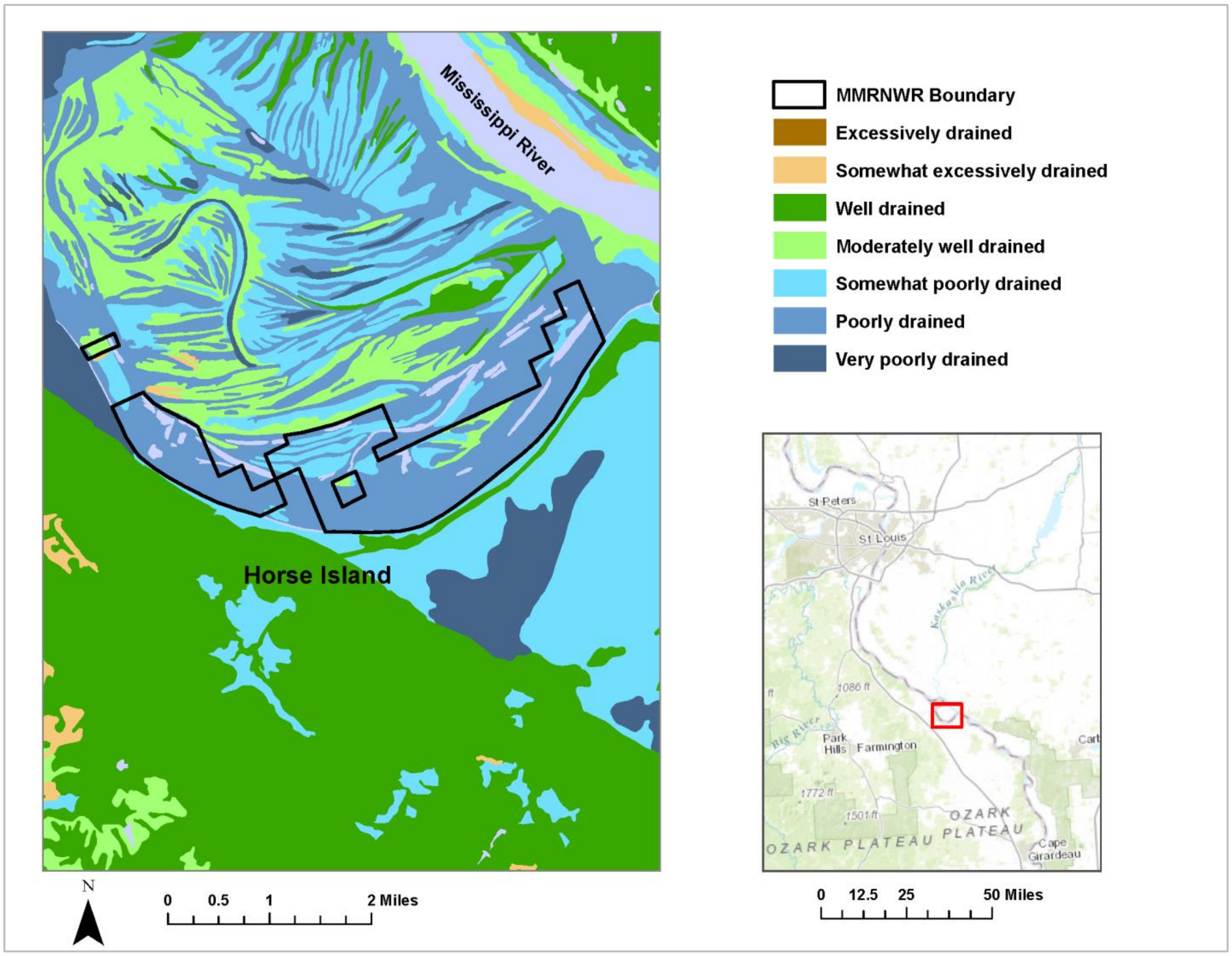

Figure 32: Soil drainage map for Horse Island

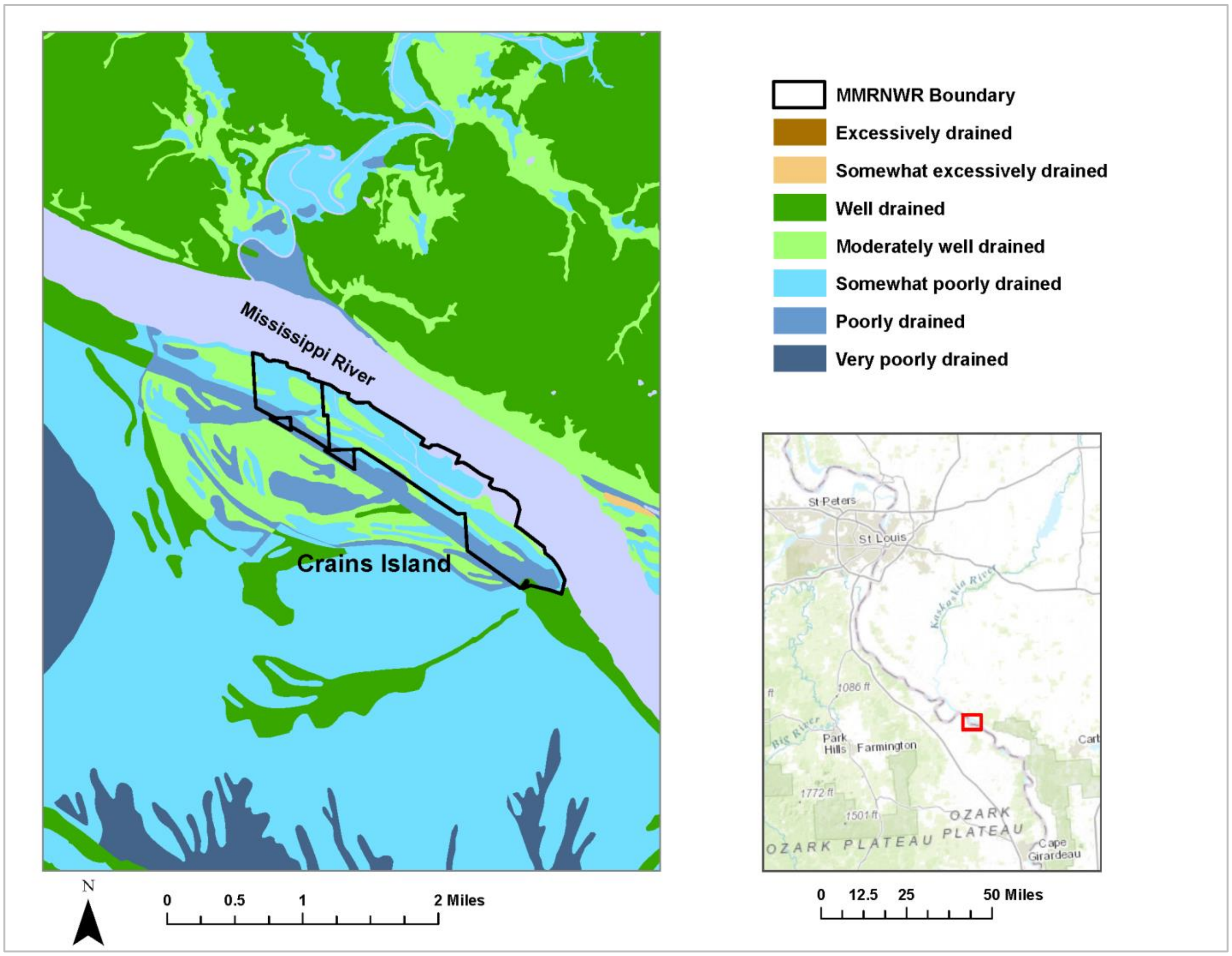

Figure 33: Soil drainage map for Crains Island

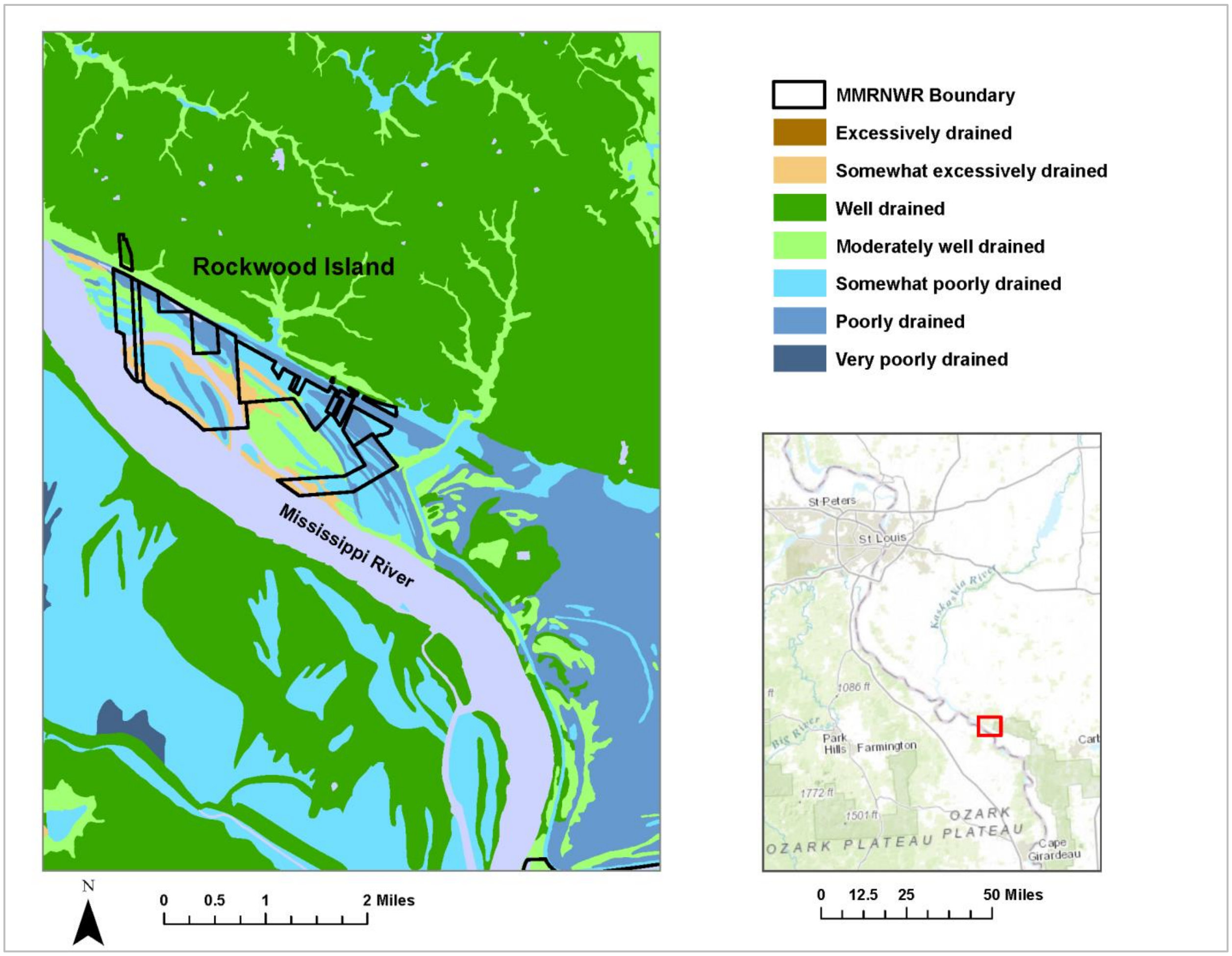

Figure 34: Soil drainage map for Rockwood Island

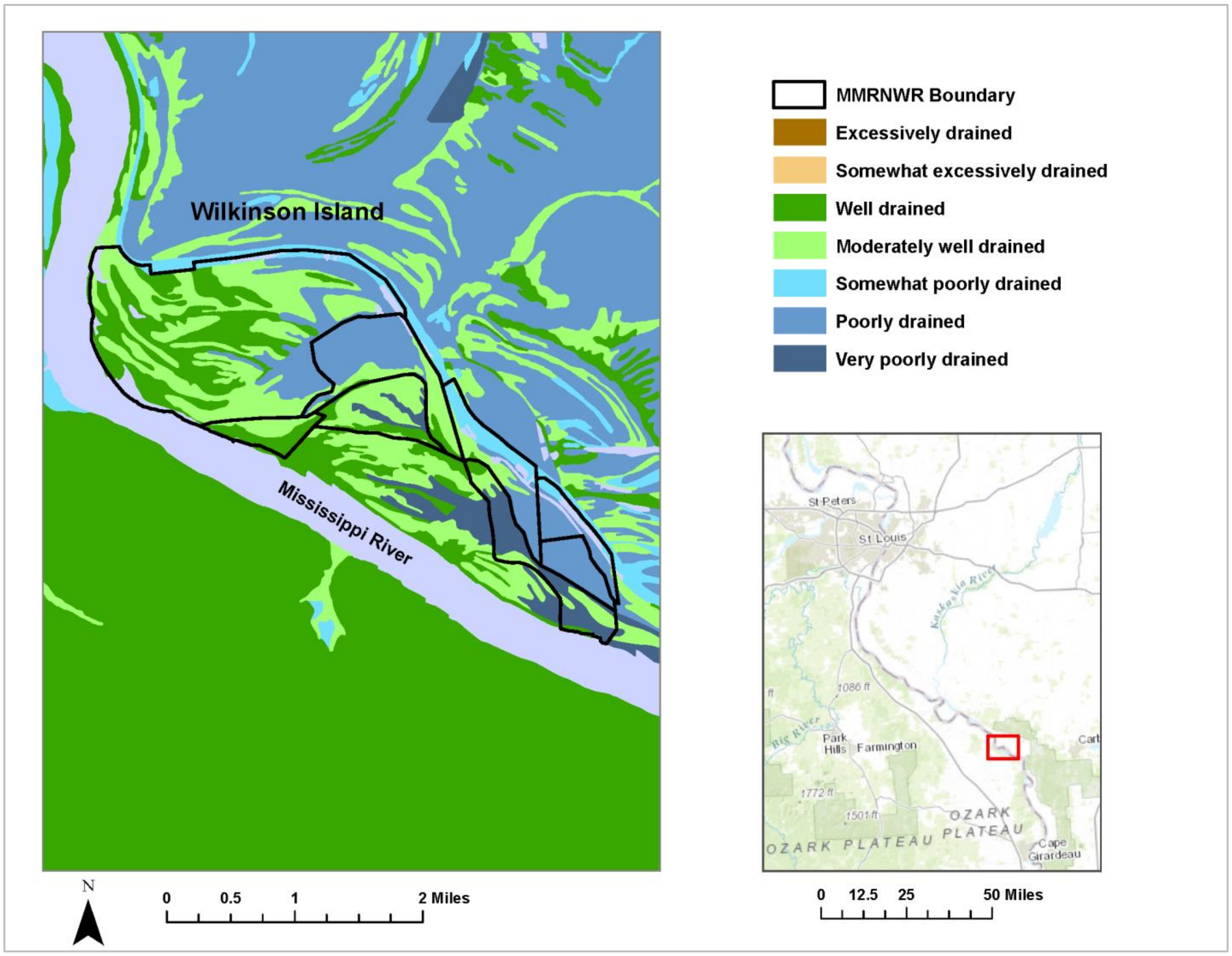

Figure 35: Soil drainage map for Wilkinson Island

Appendix C: National Wetlands Inventory (NWI)

Division	Wetland Type	GIS Acres	% of Total
Meissner Island	Freshwater Forested/Shrub Wetland	12.7	69.2
	Freshwater Pond	5.7	30.8
	Total	18.4	100
Harlow Island	Freshwater Emergent Wetland	304.6	48.4
	Freshwater Forested/Shrub Wetland	318.9	50.7
	Riverine	5.9	0.9
	Total	629.5	100
Beaver Island	Freshwater Emergent Wetland	0.7	0.3
	Freshwater Forested/Shrub Wetland	250.5	97.8
	Riverine	4.9	1.9
	Total	256.1	100
Horse Island	Freshwater Emergent Wetland	78.6	5.2
	Freshwater Forested/Shrub Wetland	1329.8	87.6
	Freshwater Pond	25.8	1.7
	Lake	23.5	1.5
	Riverine	59.7	3.9
	Total	1517.3	100
Crains Island	Freshwater Emergent Wetland	7.4	1.9
	Freshwater Forested/Shrub Wetland	270.5	70.8
	Freshwater Pond	2.7	0.7
	Riverine	101.7	26.6
	Total	382.3	100
Rockwood Island	Freshwater Emergent Wetland	6.7	0.9
	Freshwater Forested/Shrub Wetland	590.0	82.7
	Freshwater Pond	11.1	1.6
	Riverine	105.3	14.8
	Total	713.1	100
Wilkinson Island	Freshwater Emergent Wetland	5.4	0.4
	Freshwater Forested/Shrub Wetland	1409.4	92.1
	Freshwater Pond	25.6	1.7
	Riverine	90.7	5.9
	Total	1531.1	100

Table 11: NWI wetland type acreage for Refuge divisions

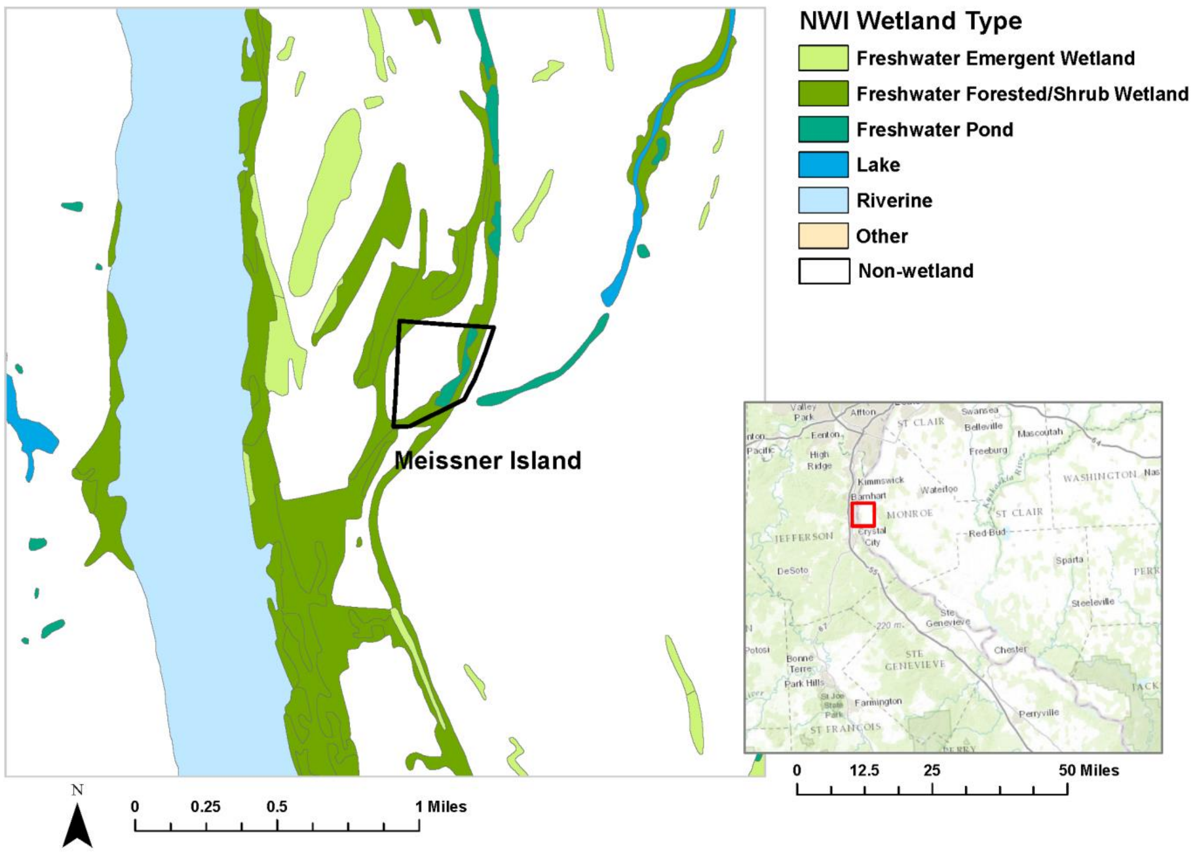

Figure 36: NWI map of Meissner Island division

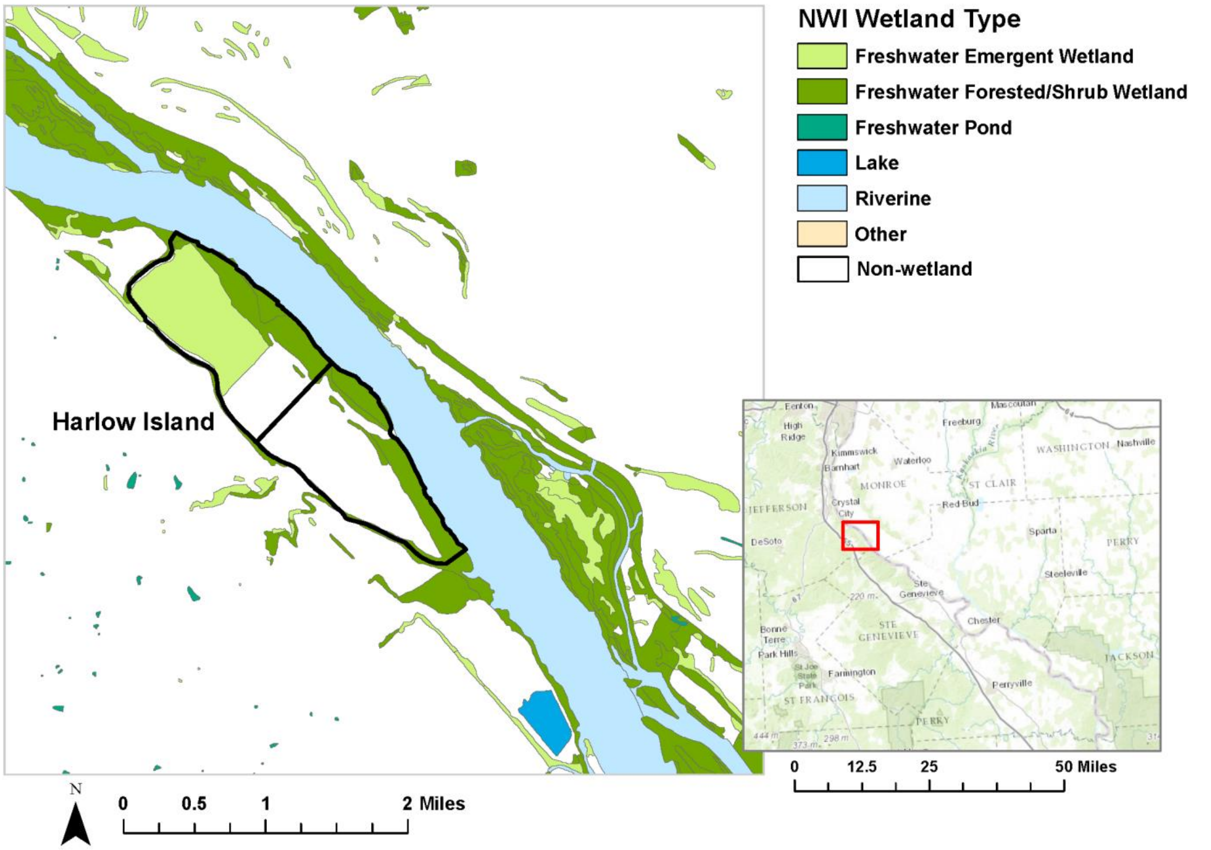

Figure 37: NWI map of Harlow Island division

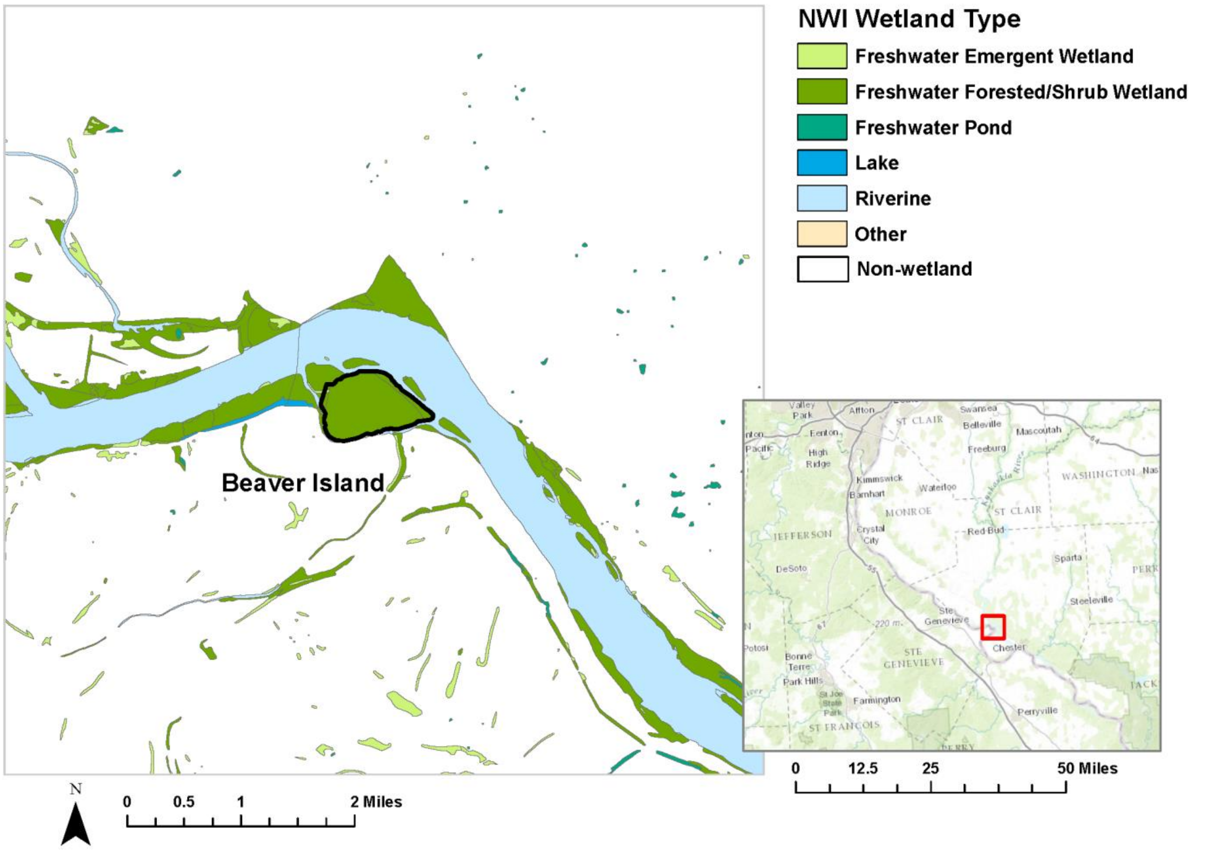

Figure 38: NWI map of Beaver Island division

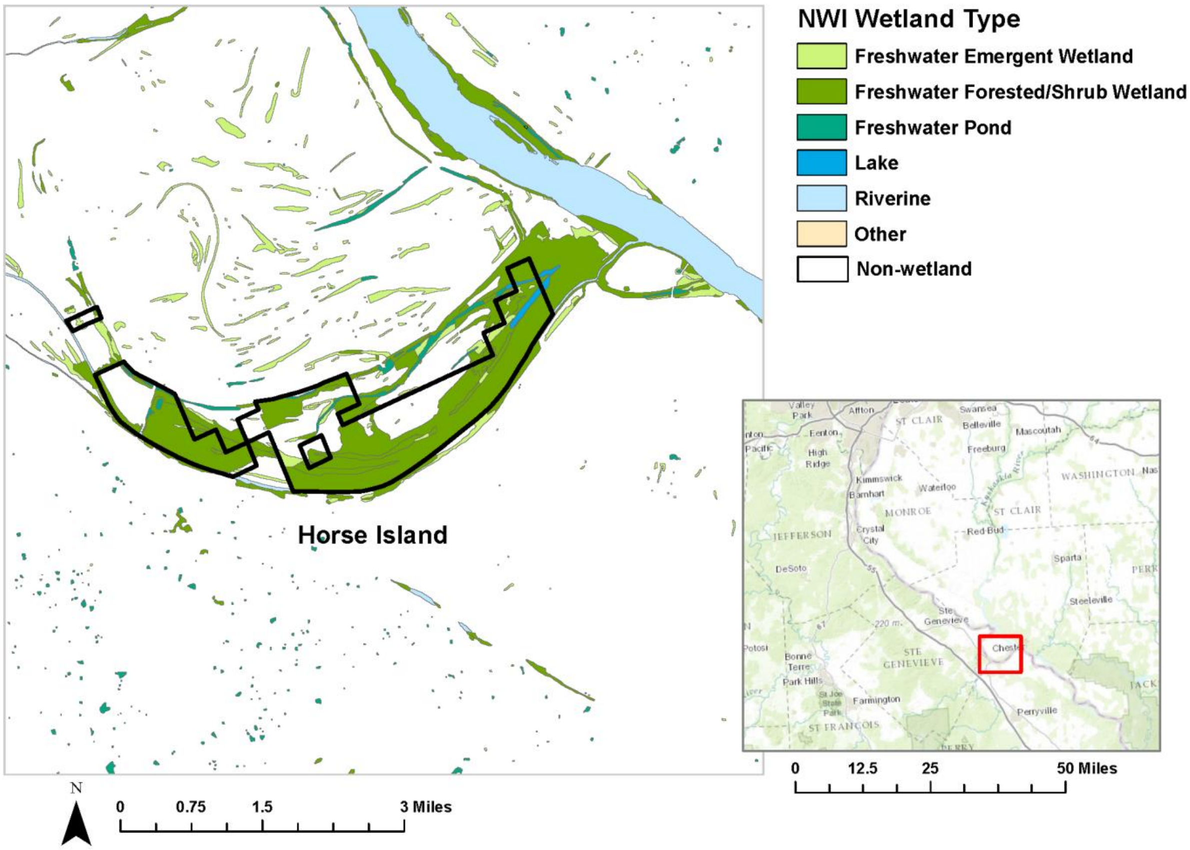

Figure 39: NWI map of Horse Island division

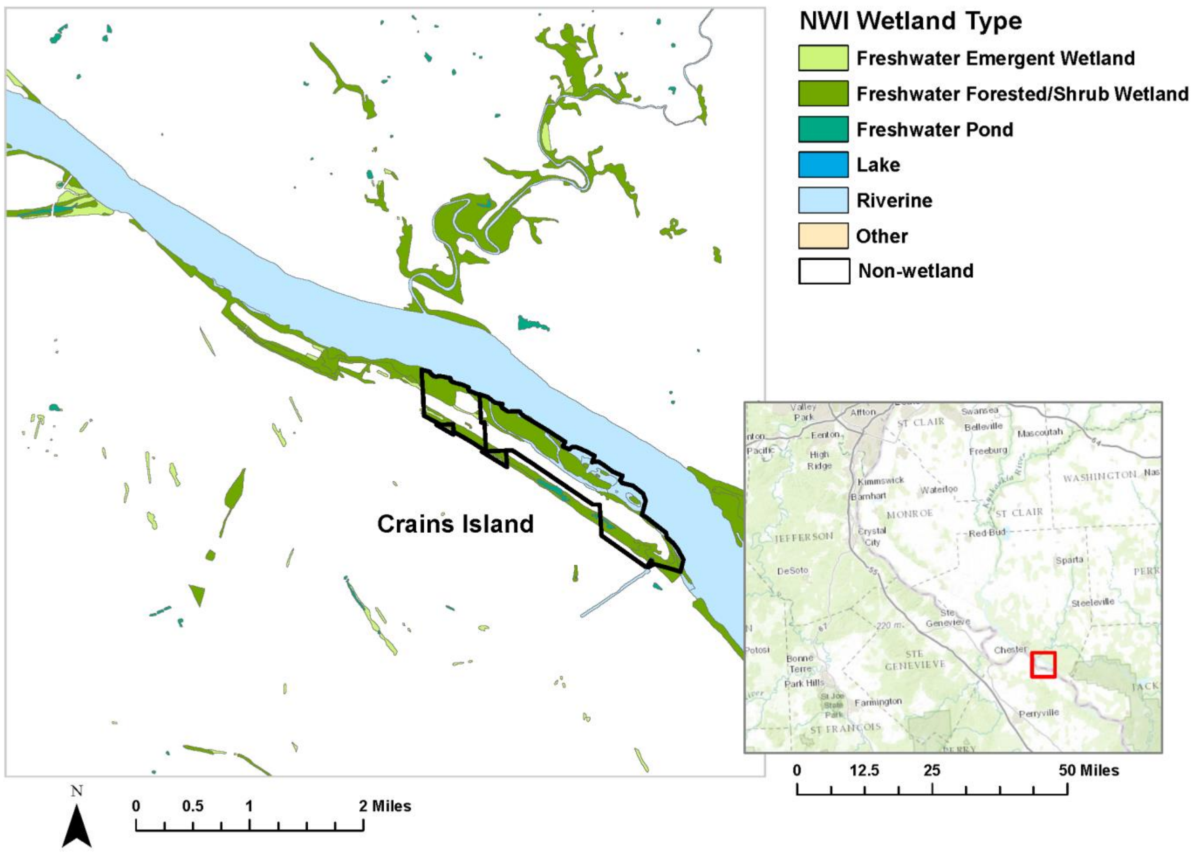

Figure 40: NWI map of Crains Island division

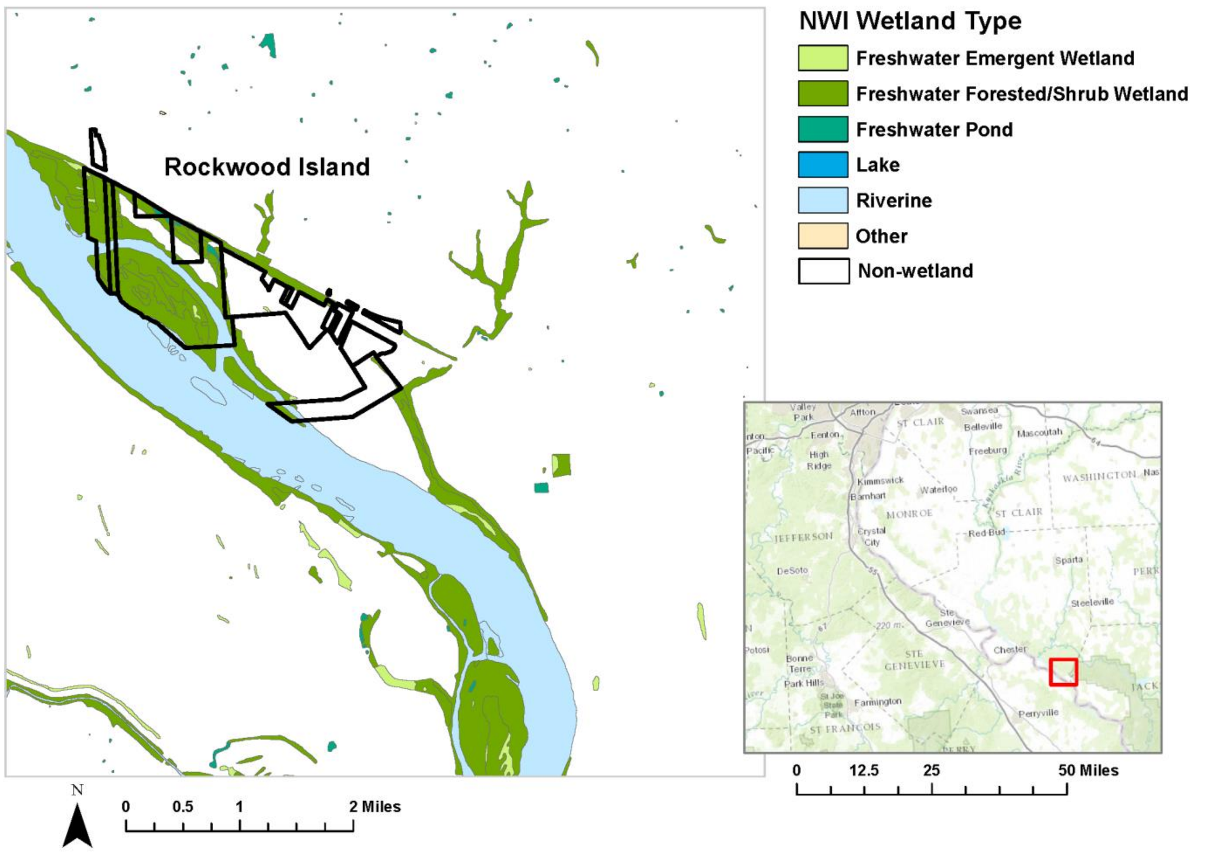

Figure 41: NWI map of Rockwood Island division

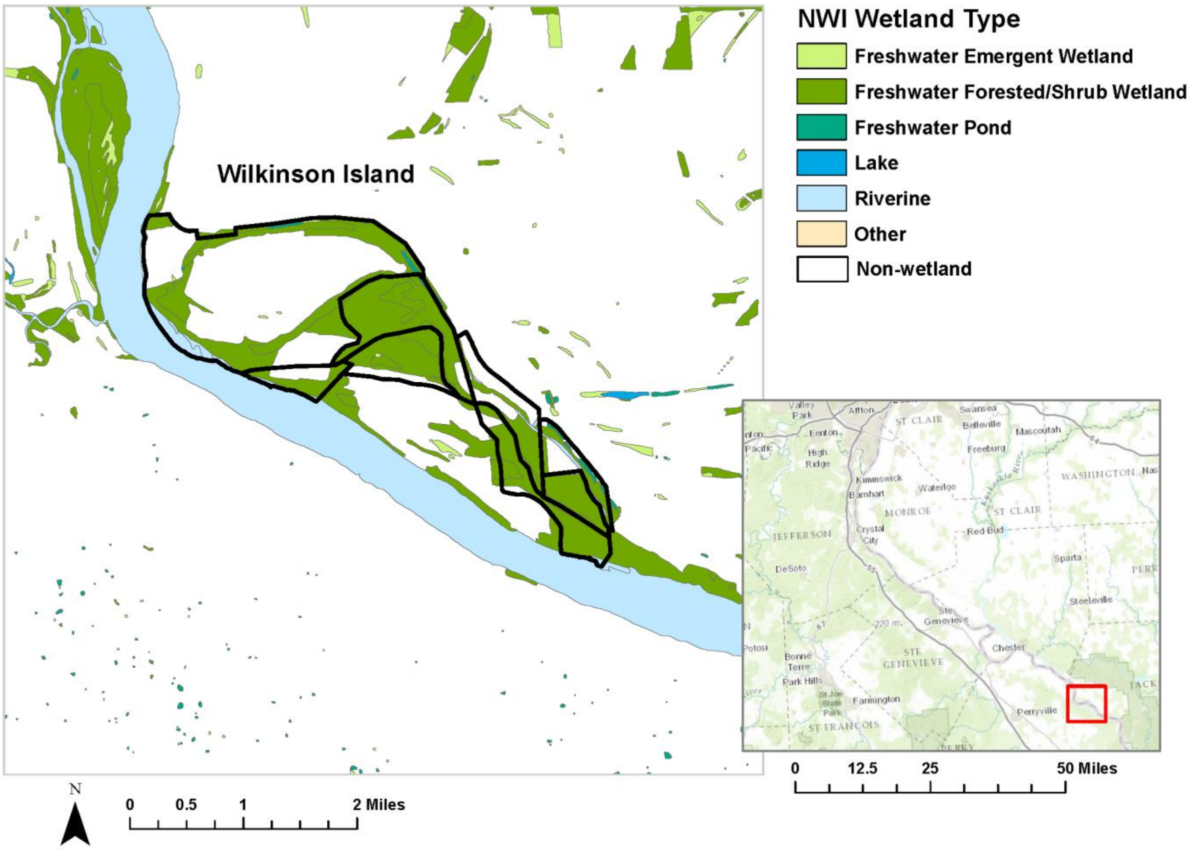

Figure 42: NWI map of Wilkinson Island division

Appendix D: National Hydrography Dataset (NHD)

Division	Description	Total (Miles)	Total (%)	Named Features	Total (Miles)
Meissner Island	**There are no NHD flowlines for Meissner Island.**	NA	NA	NA	NA
Harlow Island	Stream/River- Intermittent	0.9	8.7		
	Stream/River- Perennial	5.3	51	Muddy Creek	0.3
				Saline Creek	0.2
	Artificial Path	4.1	40.3	Mississippi River	3.6
	Total	10.3	100	Total	4.2
Beaver Island	Stream/River- Perennial	0.1	7.1	Idlewild Slough	0.1
	Artificial Path	0.9	92.9	Idlewild Slough	0.2
				Mississippi River	0.1
	Total	0.98	100	Total	0.4
Horse Island	Stream/River- Intermittent	4.6	29.0		
	Stream/River- Perennial	0.9	6.0	Saint Laurent Creek	0.4
	Artificial Path	10.3	65.0	Old River	7.3
				Saint Laurent Creek	0.009
	Total	15.8	100	Total	7.7
Crains Island	Stream/River- Intermittent	0.98	15.6	Missouri Chute	0.8
	Stream/River- Perennial	0.9	13.7		
	Artificial Path	4.4	70.7	Missouri Chute	0.2
				Mississippi River	3.7
	Total	6.3	100	Total	4.7
Rockwood Island	Stream/River- Intermittent	6.7	67.7	Rock Creek	2.1
	Stream/River- Perennial	0.5	5.1	Degognia Creek	0.5
	Artificial Path	2.7	27.2	Mississippi River	1.9
	Total	9.8	100	Total	4.6
Wilkinson Island	Stream/River- Intermittent	5.2	30.8	Reeds Creek	0.5
	Stream/River- Perennial	5.0	29.9	Reeds Creek	0.5
	Artificial Path	6.2	37.1	Mississippi River	3.7
				Cinque Hommes Creek	0.1
				Reeds Creek	1.1
	Canal/Ditch- aqueduct	0.4	2.2	Reeds Creek	0.4
	Total	16.8	100	Total	6.2

Table 12: NHD information for Refuge divisions

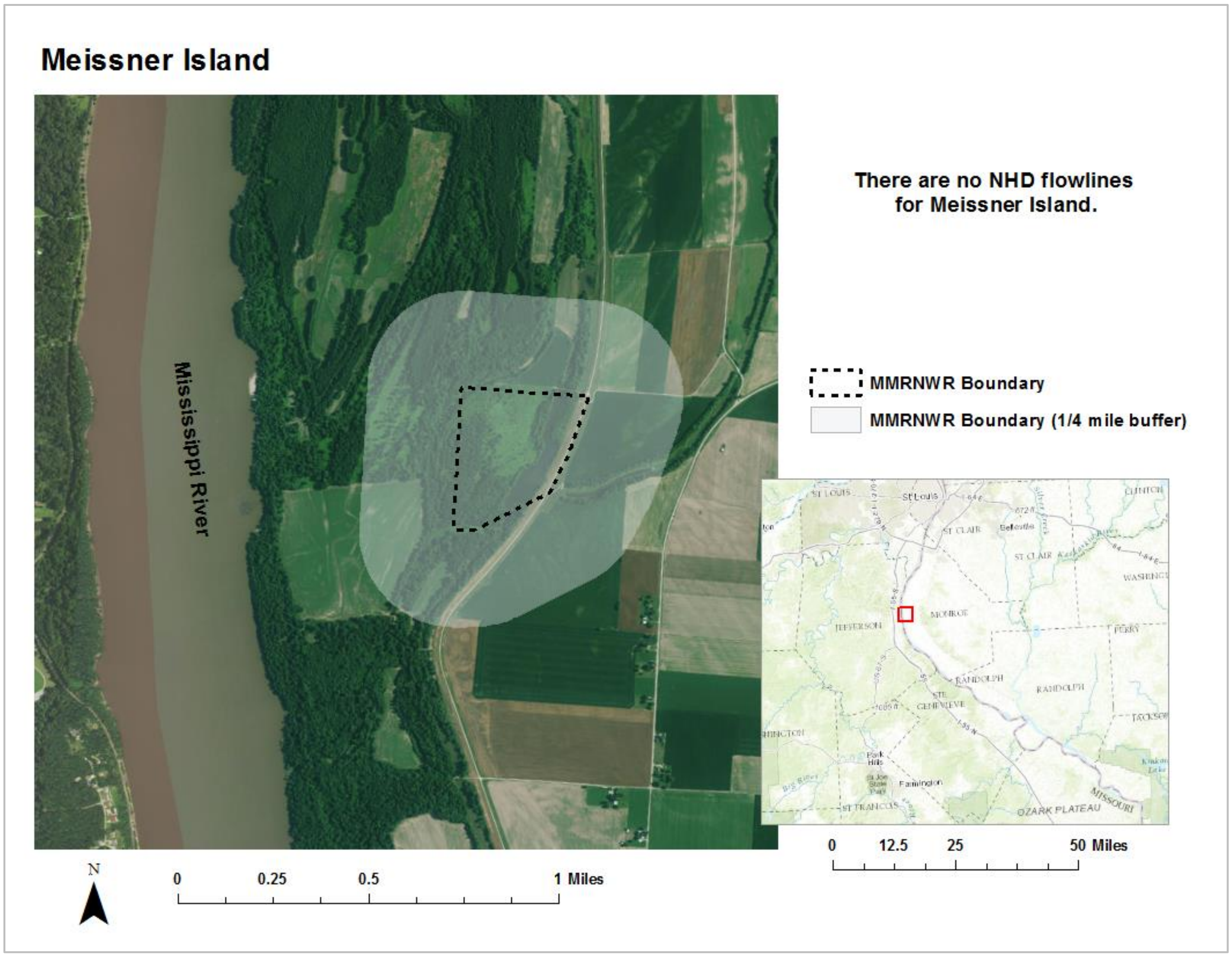

Figure 43: NHD map of Meissner Island division

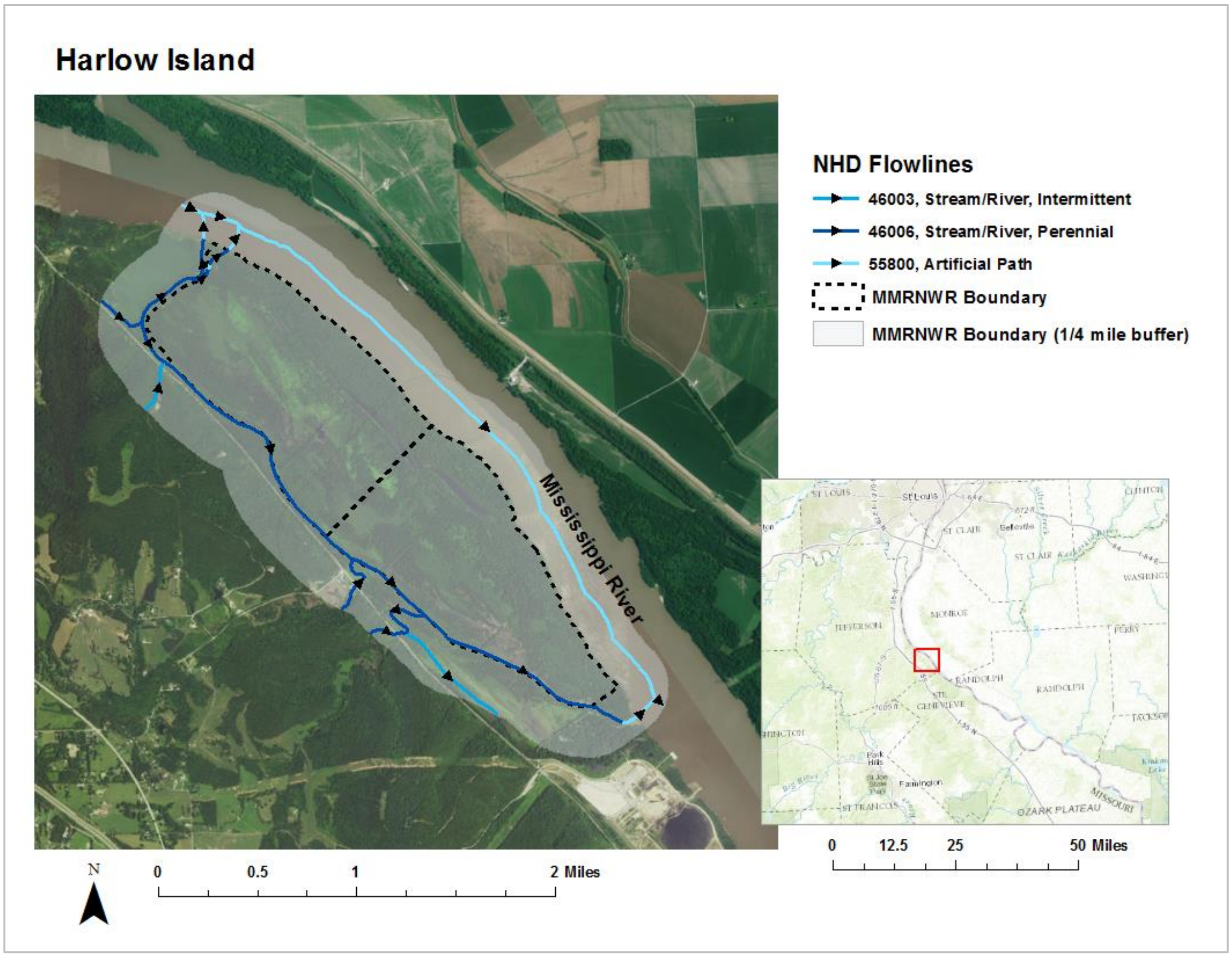

Figure 44: NHD map of Harlow Island division

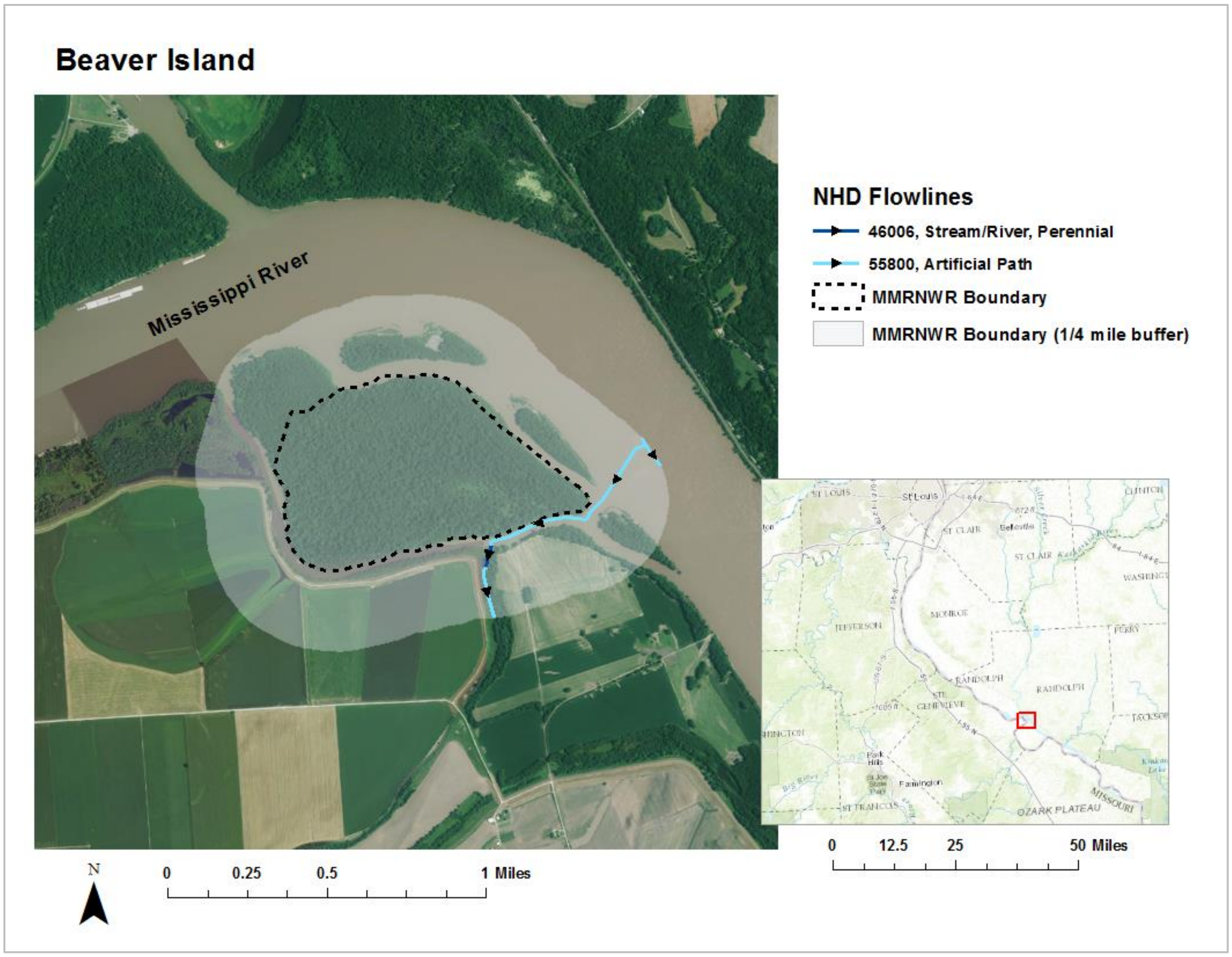

Figure 45: NHD map of Beaver Island division

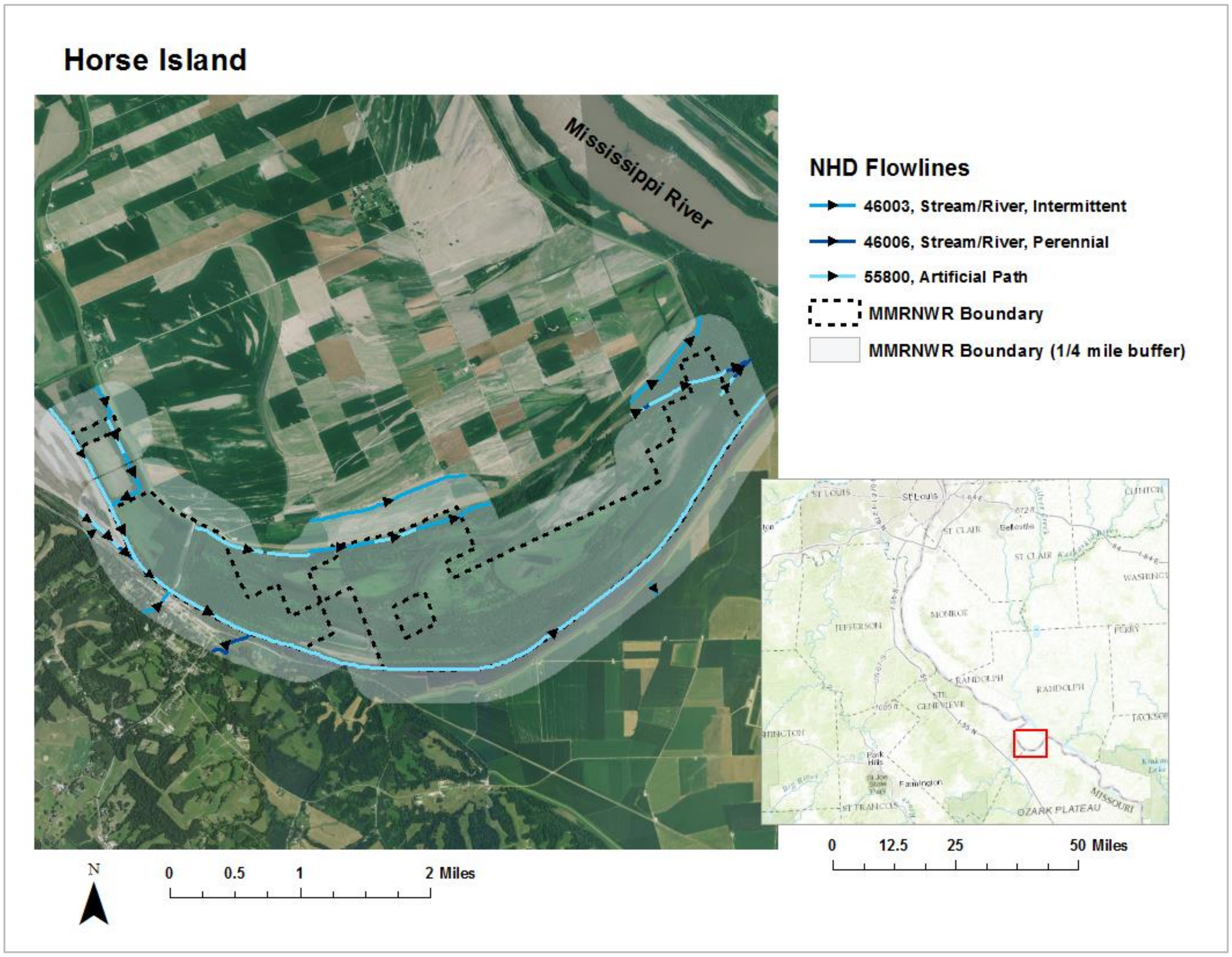

Figure 46: NHD map of Horse Island division

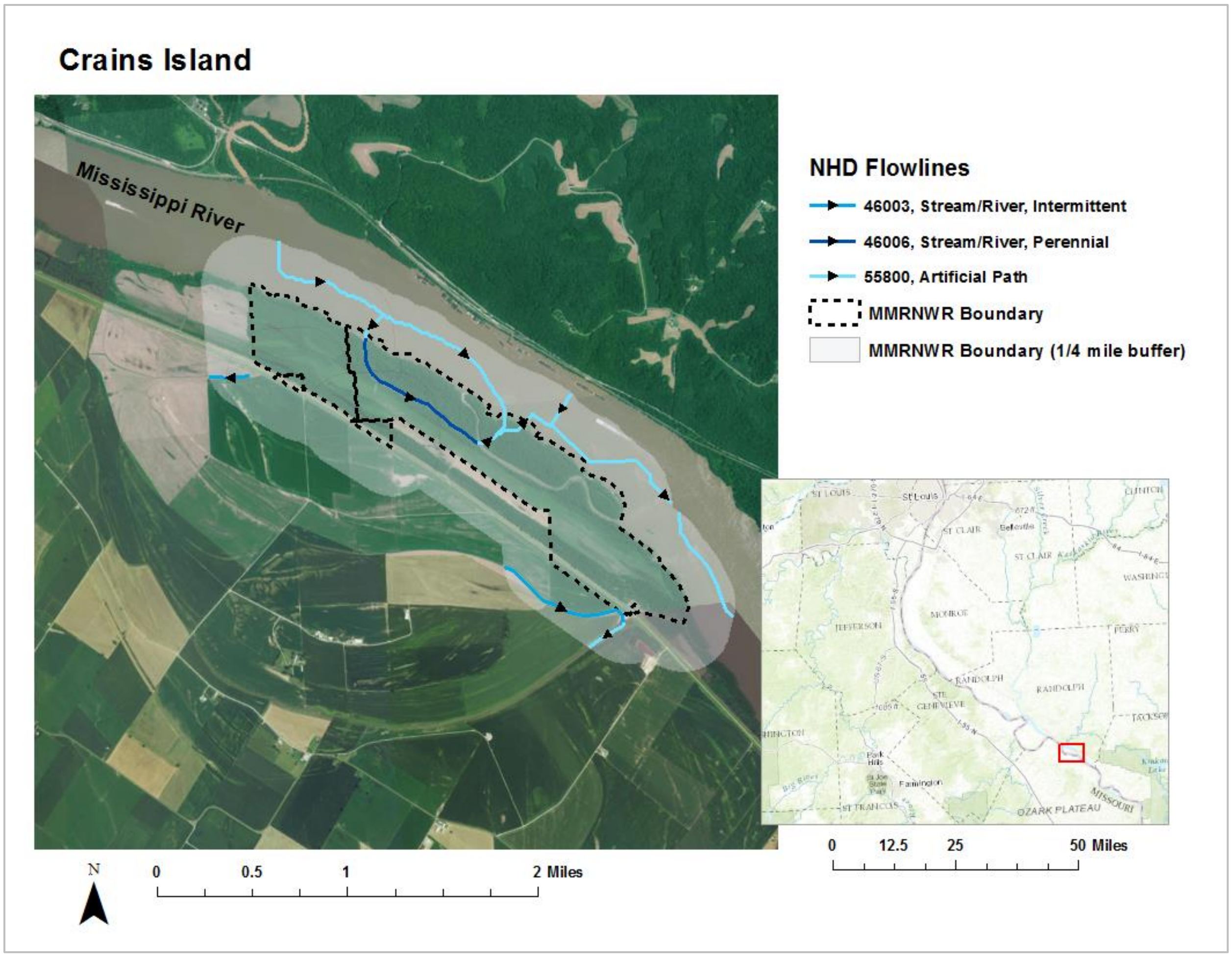

Figure 47: NHD map of Crains Island division

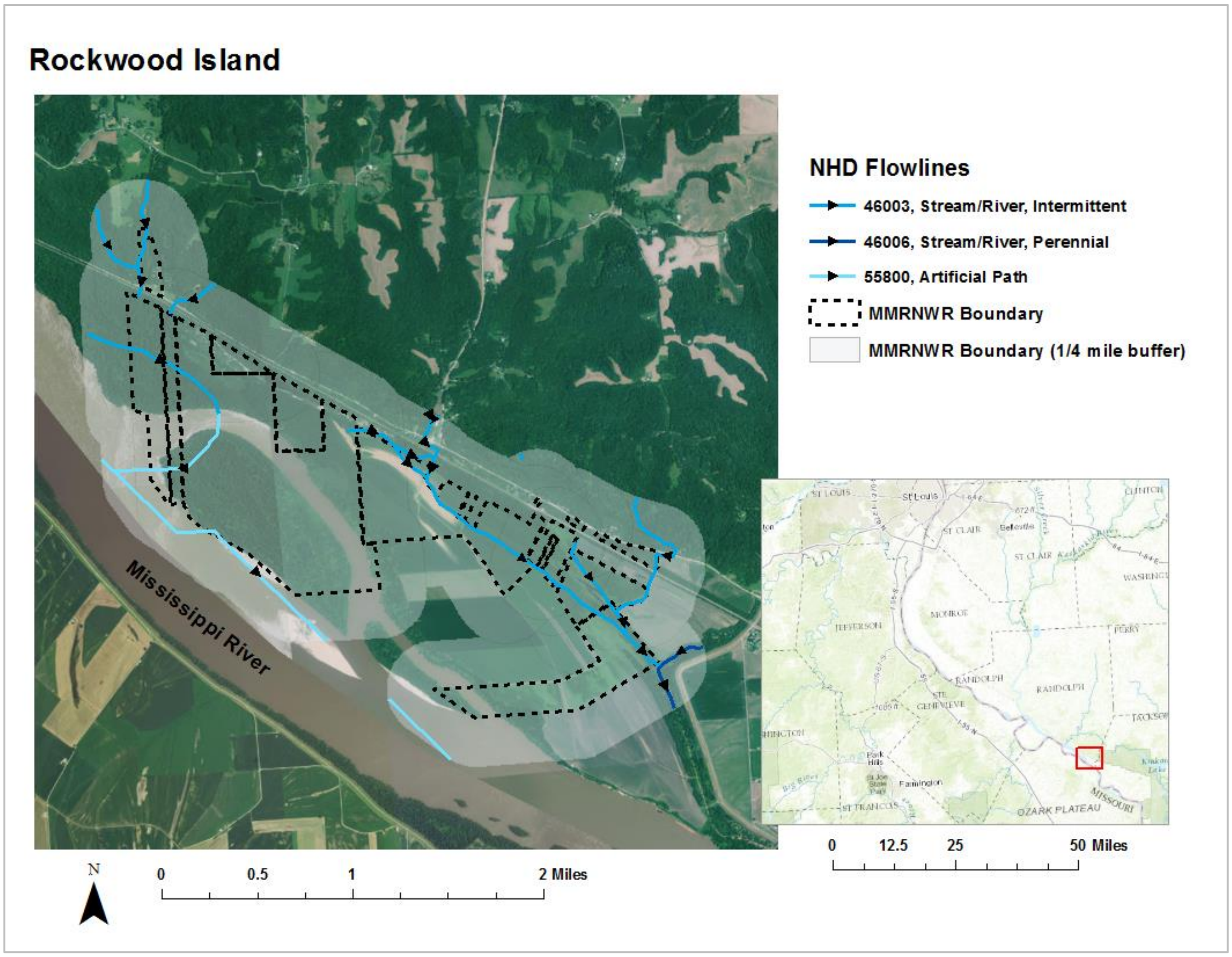

Figure 48: NHD map of Rockwood Island division

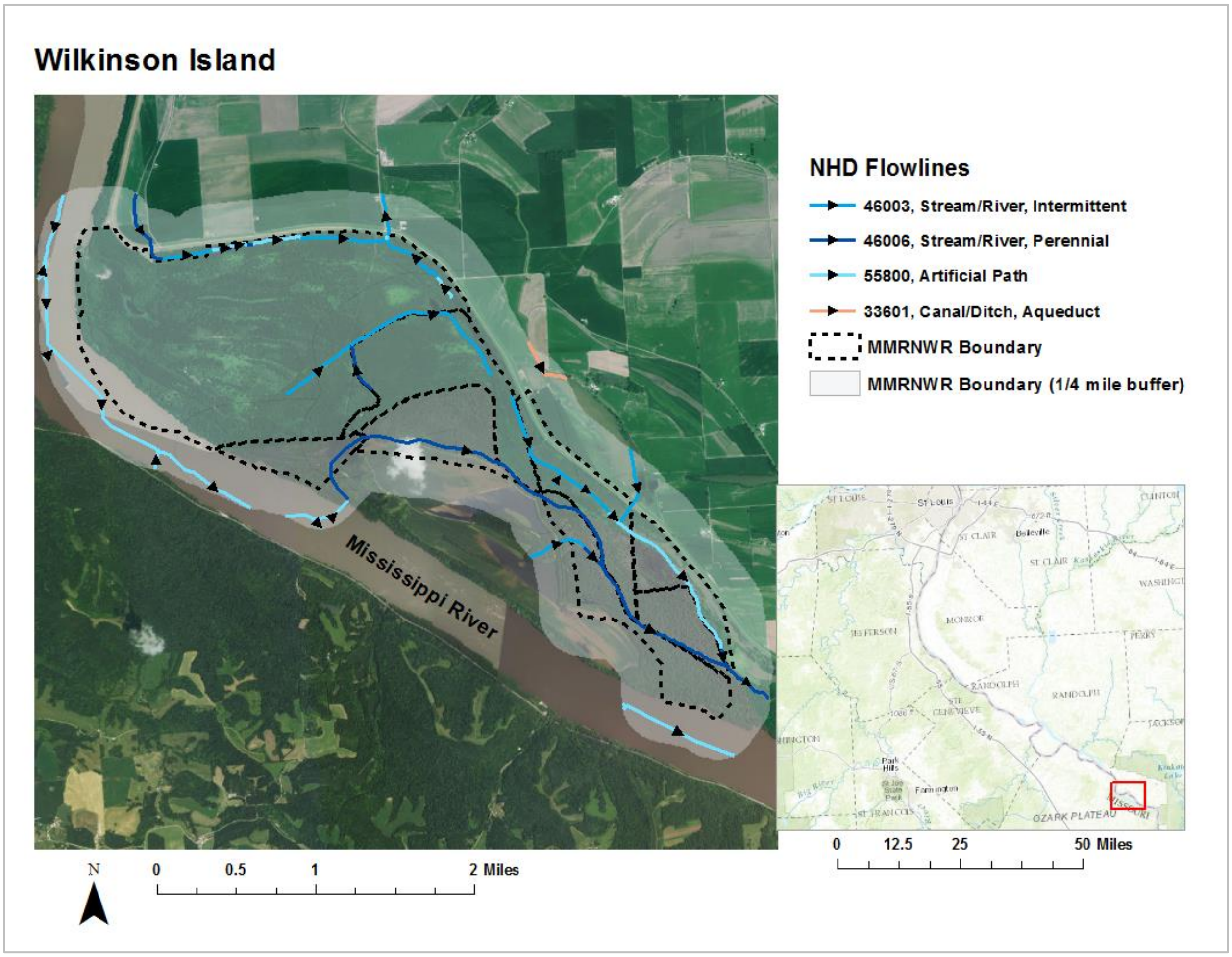

Figure 49: NHD map of Wilkinson Island division

Appendix E: Climate Data

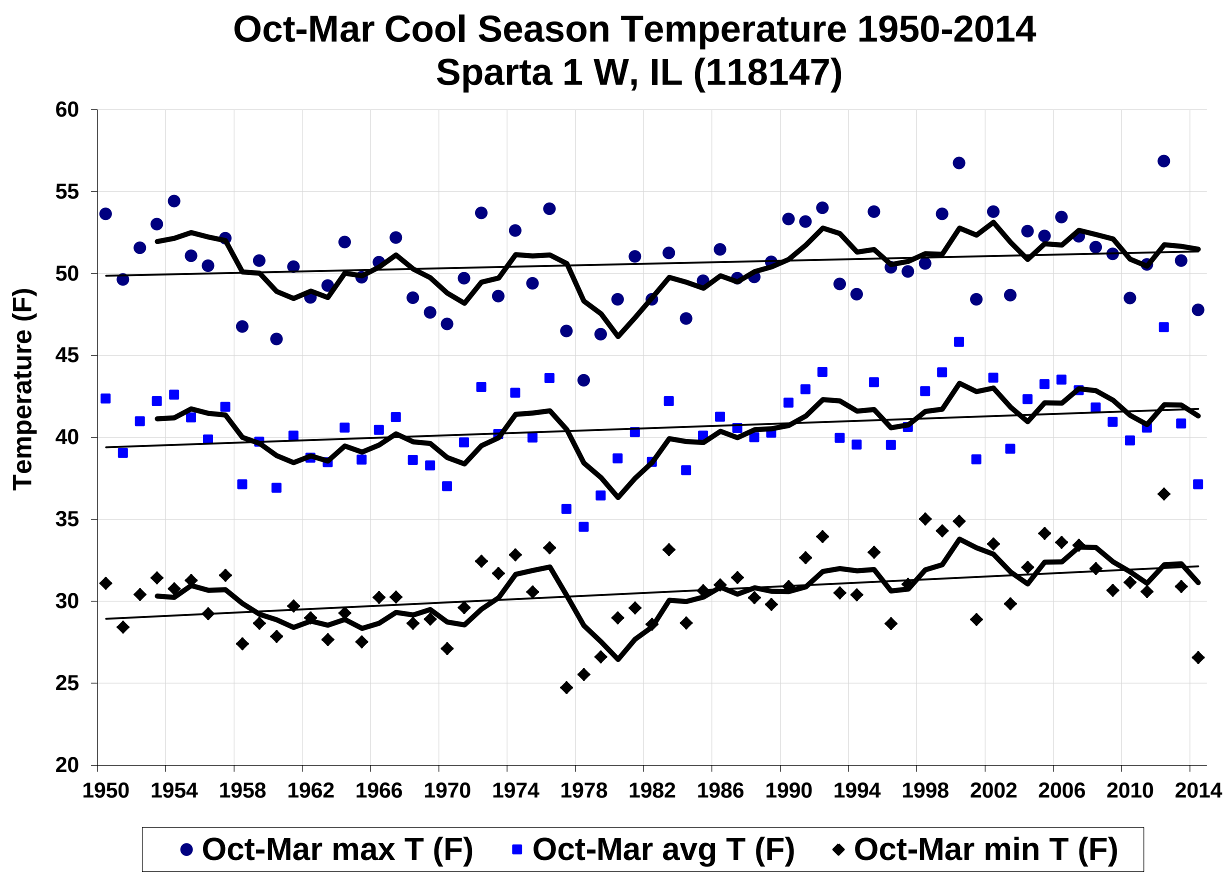

Figure 50: Cool season temperature trends near Sparta, IL (1950-2014)

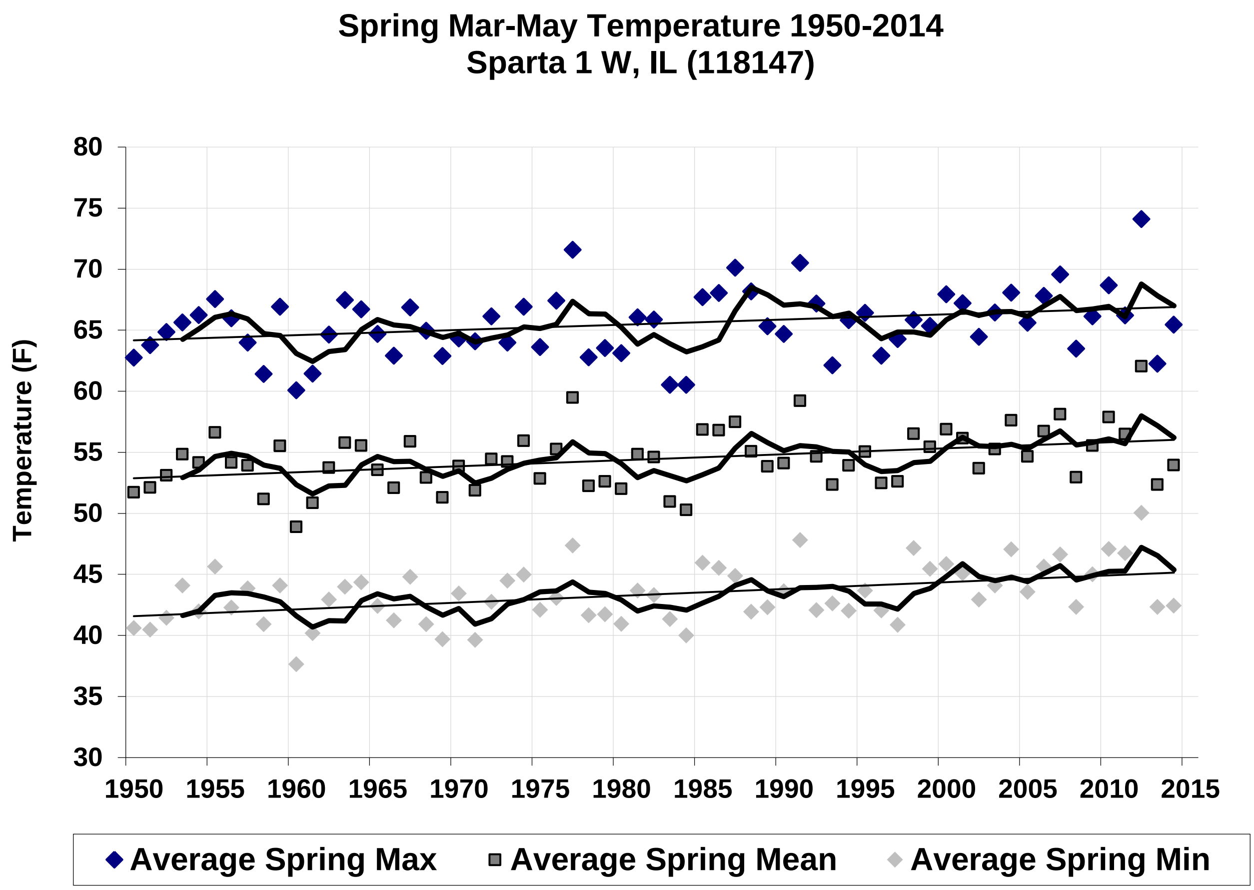

Figure 51: Spring temperature trends near Sparta, IL (1950-2014)

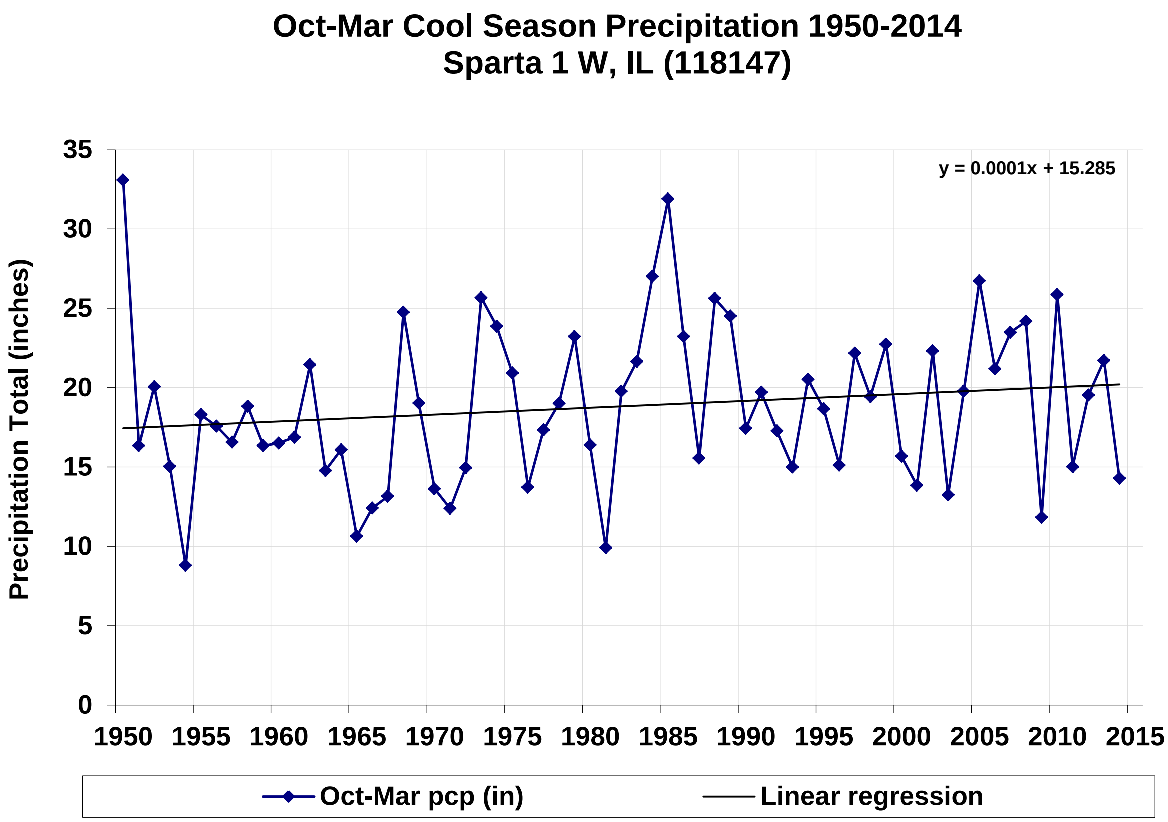

Figure 52: Cool season precipitation trends near Sparta, IL (1950-2014)

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